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AUTO TECH

Technical Training Manual

CRD Advanced System Diagnosis

- Diagnosis using your scan tool
- Fuel system bleeding
- Fuel injector calibration codes
- DPF regeneration procedures

$95

Repco

Common Rail Diesel (CRD)
Advanced System Diagnostics

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Look for these symbols throughout the manual

Note: *Indicates a point of interest*

Caution: *Indicates the risk of minor injury, special procedure or possible damage to a component*

Warning: *Indicates the risk of serious or life threatening injury*

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Introduction

INTRODUCTION

The Common Rail Diesel (CRD) system of today has evolved from its earliest incarnation developed in the late 1960's. However, it wasn't until the 1990's that full scale production of electronically controlled CRD reached the heavy vehicle market. Shortly afterward this technology was adapted to meet the requirements of light vehicles and by the end of the 90's electronically controlled CRD had been widely adopted by light vehicle manufactures.

In Australia, the delay in adopting more stringent emission laws (EURO 4 equivalent) meant that many vehicles built specifically for our local market did not receive the new CRD engines until 2006. Since this time the CRD powered vehicles have increased the light vehicle diesel market to 30% of vehicles sold.

With CRD systems continuing in popularity today's automotive repair workshop cannot afford to miss out on this lucrative share of the market place. This training clinic looks at a number of CRD technologies and investigates the problem-solving requirements to successfully diagnose and repair these vehicles.

WHY DIESEL?

Diesel engines have a heritage of being dirty, smelly and noisy. So why are they still a viable option?

Diesel has roughly the same carbon content as ULP. However, it is ≈12% more dense, making it ≈12% more efficient. To calculate the Net Heat Content the carbon content and density are calculated. *Table 1* provides the typical Net Heat Content of common fuel types.

Table 1: Net heat content of common fuels

Fuel Type	Net Heat Content
Diesel	38.6 MJ/L
BioDiesel	≈35 MJ/L
Unleaded Petrol	34.8 MJ/L
E10	33.7 MJ/L
E85	33.1 MJ/L
Ethanol	23.5 MJ/L
AutoGas (LPG)	≈27 MJ/L

Higher compression & other factors mean that Diesel engines are up to 40% more efficient than ULP engines.

On average, the diesel engine emits more emissions per litre of fuel than a ULP engine, but because of the reduced fuel consumption the average CRD with diesel exhaust after treatment works out to be up to 20% lower in emissions.

SO WHY COMMON RAIL?

To attain minimal emissions the combustion conditions must be optimised, the positive side effect of this is optimal performance.

CRD systems increase the volatility of the diesel fuel in the combustion chamber by increasing the injection pressure (up to 200kPa) and using injector nozzles with as many as 9 delivery holes. A higher accuracy of delivery is achieved with individual cylinder timing control, multiple fuel injections and individual cylinder adaption. The complexities of achieving this with mechanical fuel control would be economically impossible. Lastly, the use of a Diesel Exhaust After Treatment (DEAT) such as a Diesel Particulate Filter (DPF) and/or Select Catalyst Reduction (SCR) reduces exhaust emissions further. This enables CRD engines to achieve equivalent and sometimes lower exhaust emissions than comparable petrol engines.

PHASES OF COMBUSTION

The names of the combustion phases were derived long before electronically controlled CRD. You'll notice that these phase names match the physical attributes of mechanical injection systems, in contrast the cylinder effects of a CRD system are somewhat different.
The four phases of diesel combustion are:

1. Delay Period
2. Uncontrolled Burning
3. Controlled Burning
4. After Burning

The following figures *(Figure 1 and 2)* show the combustion phases of a diesel engine and compare the operation of a mechanically injected phase against that of the CRD phase. The major aspects of each graph are as follows:

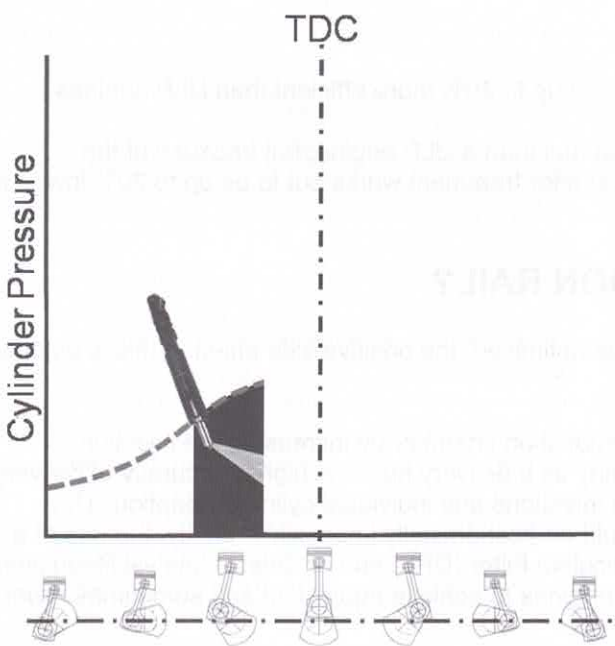
a. Vertical axis = Cylinder Pressure
b. Horizontal axis = Crankshaft Angle or Time
c. Centre line = Top Dead Centre
d. Dashed Line = The native cylinder pressure created by piston stroke
e. Solid Line = The cylinder pressure created by combustion

Delay Period

Mechanical Injection

The mechanical injection graph shows the gradual increase of native cylinder pressure with piston stroke. When the fuel is injected into the cylinder a number of factors prevent it from igniting (lack of temp in the cylinder, large amount of fuel delivered, lack of fuel atomisation). This is where the phase name "Delay Period" is derived.

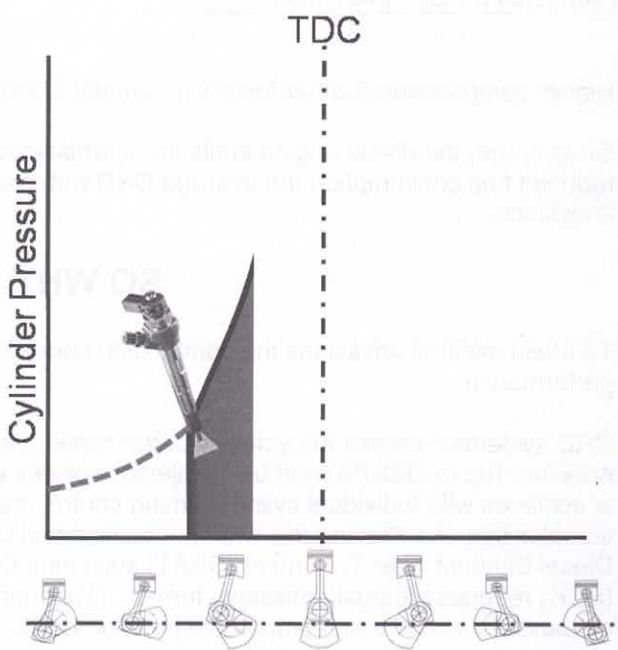
Figure 1: Delay Period – Mechanical Injection



Common Rail Injection

The CRD graph shows the same gradual increase of native cylinder pressure as the mechanically injected system. However when the fuel is injected it is only a very small amount, it is delivered from much higher pressure creating a better atomised sample than the mechanical system. The relatively low temperature is enough to ignite the far more combustible mixture and allow the cylinder temperature and pressure to increase gradually.

Figure 2: Delay Period – Common Rail Injection



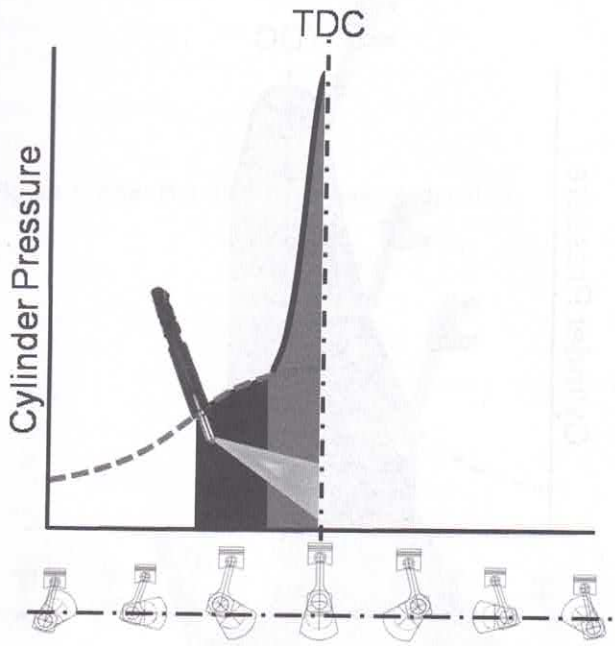
PHASES OF COMBUSTION continued...

Uncontrolled Burning

Mechanical Injection

Uncontrolled burning occurs when the temperature generated by compression finally ignites the rich and highly combustible air:fuel mixture. The result is a sudden surge in cylinder pressure. This is when the "diesel knock" noise is generated. A by-product of this rapid and uncontrolled ignition is NOX.

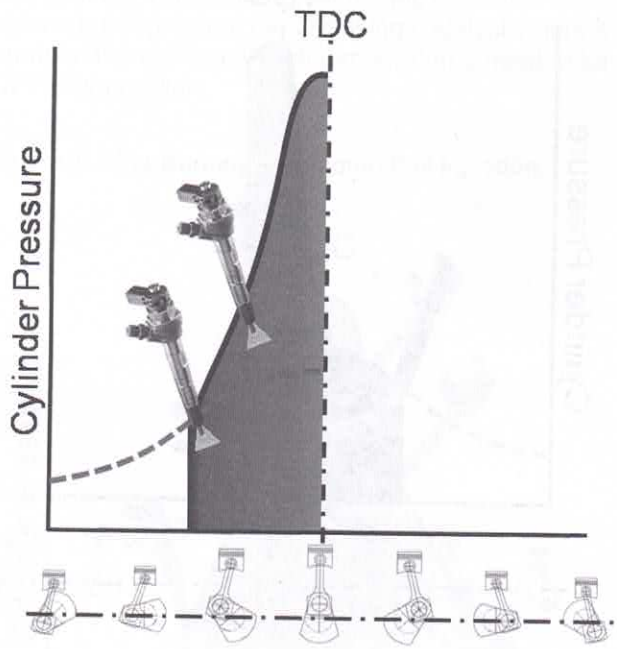
Figure 3: Uncontrolled Burning – Mechanical Injection



Common Rail Injection

With the CRD system a second pre-injection continues the increase of cylinder temperature and pressure gradually, reducing NOX gases and creating greater cylinder pressure from a lower compression ratio.

Figure 4: Uncontrolled Burning – Common Rail Injection



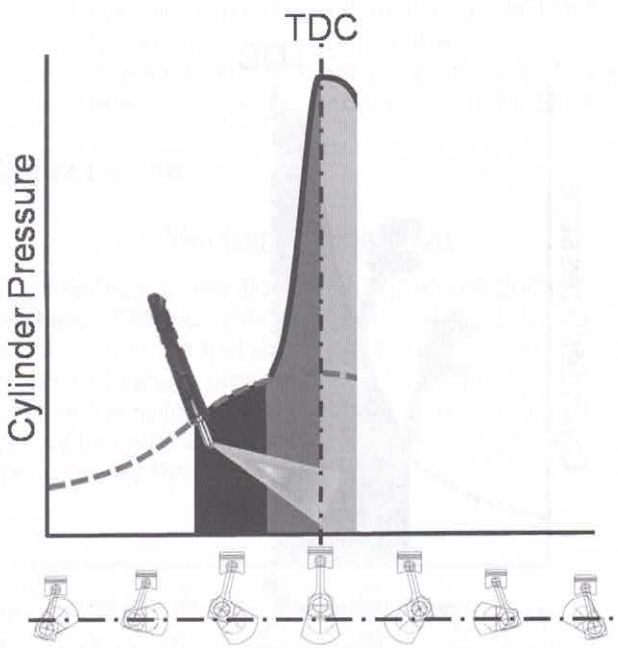
PHASES OF COMBUSTION continued...

Controlled Burning

Mechanical Injection

In the controlled burning phase, the mechanical injection system finally reaches it optimal operation. Fuel is now being delivered at the same rate as it is injected. It is in this small window of operation where maximum torque in generated.

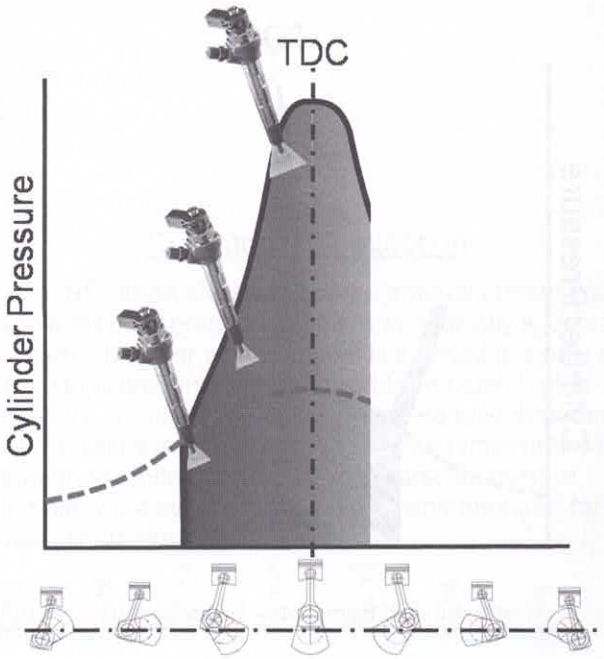
Figure 5: Controlled Burning – Mechanical Injection



Common Rail Injection

The situation of the CRD system is different. It is only a couple of degrees BTDC when the main injection is released, under optimal conditions the fuel burns rapidly and evenly creating a much broader peak torque.

Figure 6: Controlled Burning – Common Rail Injection



PHASES OF COMBUSTION continued...

After Burning

Mechanical Injection

Moving into the final phase "After Burning" the cylinder pressure of the mechanically injected system has plummeted and the fuel that is still burning in the cylinder no longer has any benefit. Once the cylinder pressure drops further the remaining fuel stops burning and the remnants (unburnt fuel/particulate matter/soot and other gases) are released to the atmosphere via the exhaust pipe.

Common Rail Injection

This phase of the CRD systems offers a number of benefits:
The first post injection adds a small amount of fresh fuel, increasing the temperature of the After Burn and making it far more efficient at burning off the remnants.
The Second post injection is usually reserved for system that use a Diesel Particulate Filter (DPF). The second post injection occurs when the after burning had ceased. The unburnt fuel travels down the exhaust until it enters the Oxidising Catalyst where it burns at the extremely high temperatures needed for DPF regeneration.

Figure 7: After Burning – Mechanical Injection

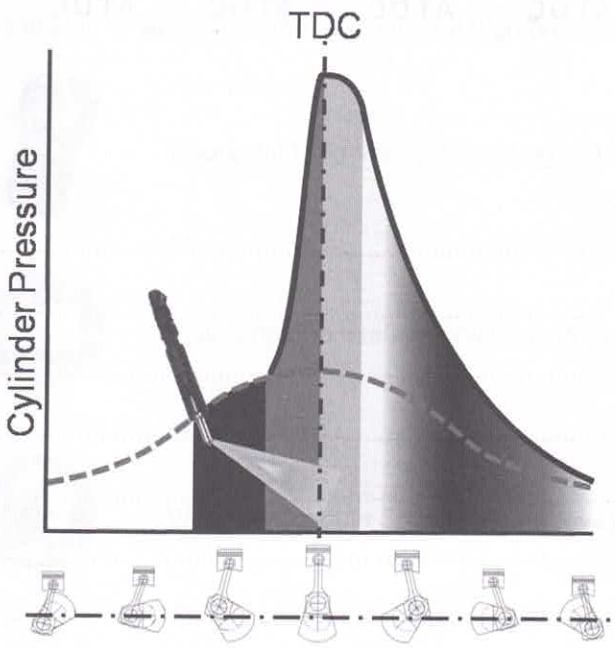
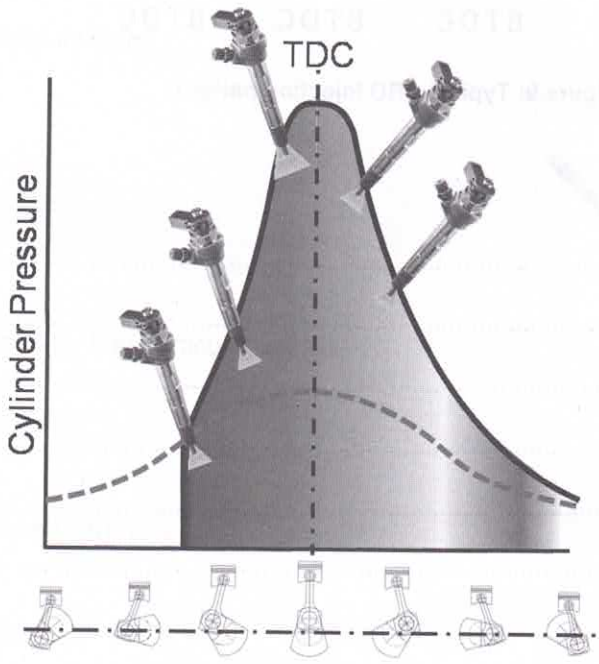


Figure 8: After Burning – Common Rail Injection



PHASES OF COMBUSTION continued...

Common Rail Injector operation

Figure 9 (below) graphs the five injections of a typical CRD combustion cycle, the five injections take less than 8ms in total.

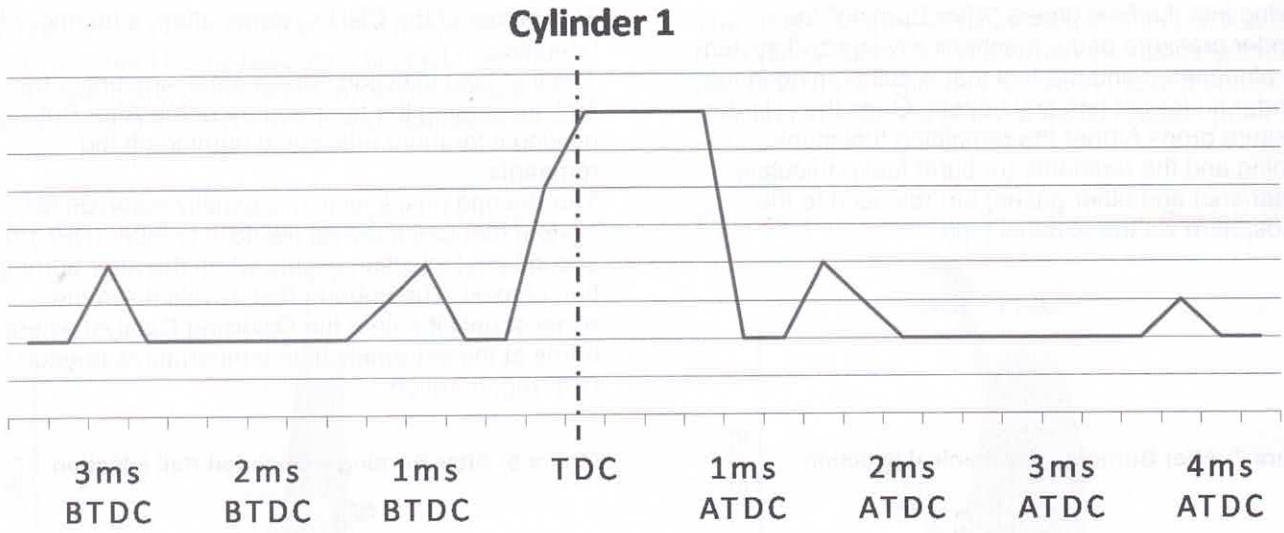


Figure 9: Typical CRD injection pattern

Safety

Warning: Extremely high fuel pressure (follow safety precautions)

Due to the high fuel pressures used in the CRD systems, extreme care must be taken when servicing and repairs are carried out.
When servicing or repairing these systems the technician must ensure that the system controls and holds the high pressures. Below are some points to note: Specific manufacturer's specifications should always be referred to.

Examples of safely decommissioning the high pressure fuel system include:

Depressurising the system using a Scan Tool

or

Following depressurisation procedure as described for that particular vehicle

and ALWAYS

Wear appropriate Safety Wear (gloves and a face shield)

LOOK FOR THE SYMBOLS THROUGHOUT THE MANUAL

Note: *Indicates a point of interest*

Caution: *Indicates the risk of minor injury, special procedure or possible damage to a component*

Warning: *Indicates the risk of serious or life threatening injury*

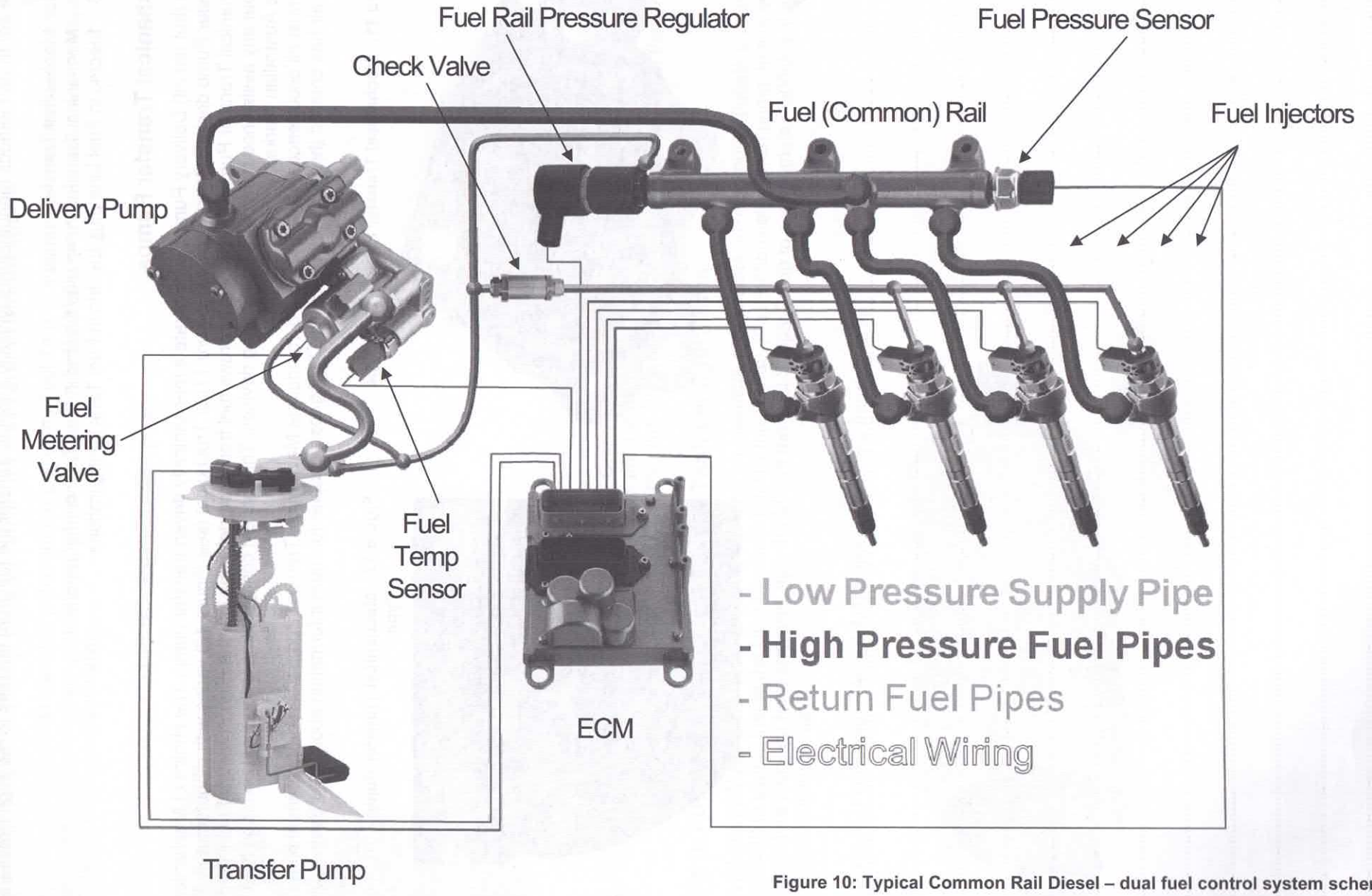


Figure 10: Typical Common Rail Diesel – dual fuel control system schematic

TRANSFER PUMPS

There are three methods manufactures typically adopt to transfer the fuel from the tank to the High Pressure Fuel Pump.

1. Mechanical Transfer Pumps
2. Mechanical Transfer Pump plus Electric in Fuel Tank configurations
3. Electric in Fuel Line plus Electric in Fuel Tank configurations

Mechanical Transfer Pumps

Most (but not all) Delivery Pumps incorporate a mechanically driven transfer pump. The choice of Mechanical Transfer Pump design, Gear Type (see *Figure 11*) or Trochoidal (see *Figure 12*) varies with manufacturer. The Mechanical Transfer Pump in this example draws fuel from the Fuel Tank into the High Pressure Fuel Pump without any assistance from auxiliary pumping devices. This system configuration is the most common type found in the Australian Market.
In almost all occurrences, vehicles using a standalone Mechanical Transfer Pump will require manual bleeding after air has entered the system, see the CRD Diagnosis chapter for more information about Fuel System Bleeding.

Figure 11: Mechanical Transfer Pump – Gear Type

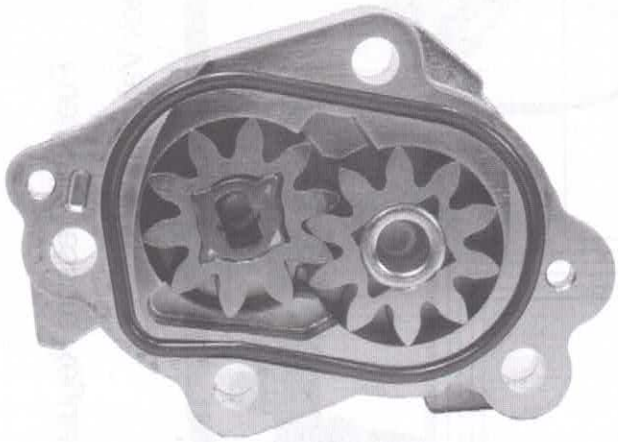
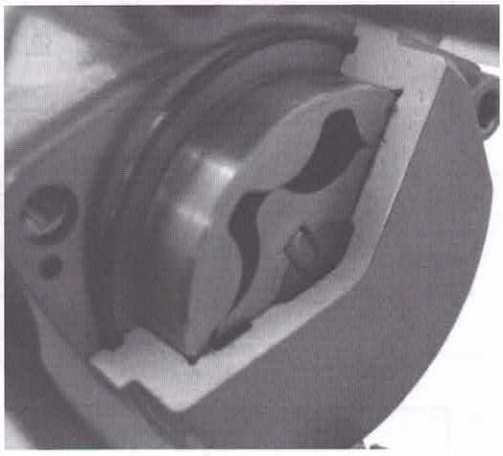


Figure 12: Mechanical Transfer Pump – Trochoidal Type



TRANSFER PUMPS continued...

Mechanical Transfer Pump plus Electric in Fuel Tank configurations

Some CRD systems use an electrical pump submerged in the Fuel Tank to supply the Transfer Pump. Systems that utilise this configuration are generally self bleeding (for air in fuel) and if some manual assistance is required it is usually just to open a bleed valve.

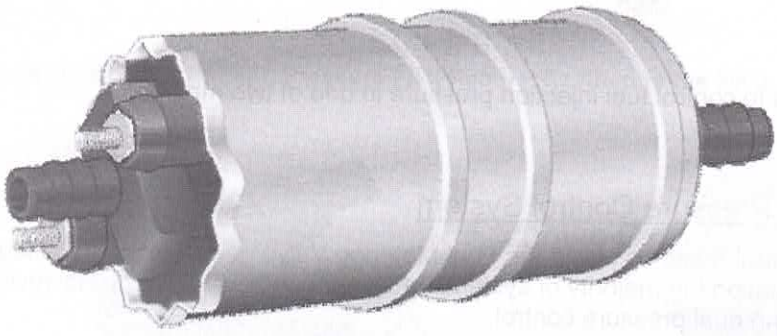
Figure 13: Typical submerged in-tank type electric transfer pump

Note: *Some systems such as the Suzuki Grand Vitara 2008 on with F9Q engine utilise an electric pump submerged in the Fuel Tank but it is used ONLY to transfer fuel across the saddle tank. The mechanically driven pump in the High Pressure Fuel Pump draws the fuel from the tank.*

Electric in Fuel Line plus Electric in Fuel Tank configurations

Some systems (VW & Audi TDI is one example) utilise an electrical intermediate/auxiliary pump (locate on the cylinder head) to supply fuel to the High Pressure Fuel Pump instead of a mechanically driven pump. In this system the fuel pressure steps up from approximately 400kPa at the Fuel Supply Pump to approximately 500kPa at the intermediate/auxiliary pump.

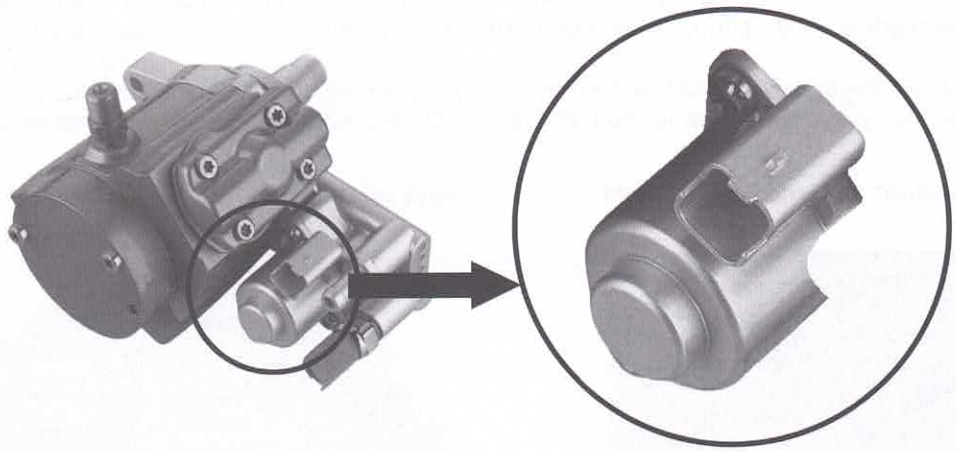
Figure 14: Typical Volkswagen/Audi (VAG) in-line type electric transfer pump



FUEL METERING VALVES

Fuel Metering Valves are used by the ECM to control the amount of fuel entering the High Pressure Fuel Pump, this in turn controls the pressure of the fuel entering the Fuel (Common) Rail. The ECM uses a Pulse Width Modulated (PWM) Duty Cycle control the solenoid while the Fuel Rail Pressure provides a feedback signal to allow the ECM to confirm that the desired output was achieved.
The Fuel Metering Valves are typically located on the inlet (low pressure) side of the High Pressure Fuel Pump.

Figure 15: Delphi Fuel Metering Valve mounted to the Delivery Pump.



There are a number of names used by different manufacturers for the Fuel Metering Valve. With this particular component the name varies so often that it was hard to choose a universal name. Some manufacturers also have difficulty settling on which name to choose and refer to this component by numerous names throughout the vehicles diagnostic information. The following are some of the names used:

- Fuel Metering Valve
- Inlet Metering Valve
- Suction Control Valve
- Fuel Quantity Regulator
- Fuel Pressure Regulator
- Fuel Rail Pressure Regulator
- Spill Control Valve
- Volume Control Valve

Fuel Pressure Control Systems

Manufactures can use the Fuel Metering Valve to control fuel injection pressure in one of two methods:
Single Pressure Control System
Dual Pressure Control System

Single Pressure Control System

As its name suggests the Single Pressure Control Systems utilise the Fuel Metering Valve as its sole fuel pressure controlling device. In the Australian CRD population the majority of systems are single pressure control. However, most current model CRD vehicles are now using dual pressure control.

Dual Pressure Control System

Dual Pressure Control Systems use the same Fuel Metering Valve as their Single Pressure Control System equivalents with the addition of a Fuel Rail Pressure Regulator. The benefit of these systems is a reduced delay between when the ECM commands a variation in fuel injection pressure and when the variation physically occurs. This leads to improved engine efficiency, performance and a reduction in exhaust emissions.
Typically in the Dual Pressure Control Systems the Fuel Metering Valve works as the primary pressure control device and in its operation it will only vary its duty by approx 5% as compared to the secondary device the Fuel Rail Pressure Regulator which is used to "fine tune" the rail pressure and changes its duty by as much as 30%.

HIGH PRESSURE FUEL PUMPS

The High Pressure Fuel Pump is a mechanically driven (Gear, Chain or Belt) pumping unit capable of creating extremely high fuel pressure. Typically of one, two or three piston configurations are used with the number of pistons used being based upon design, size limitations and efficiency rather than engine capacity. This means that some larger engines use one and two piston pumps, while some compact four cylinder engines utilise a three piston pump.

Figure 16: Bosch single piston High Pressure Fuel Pump – As fitted to Volkswagen Audi Group vehicles

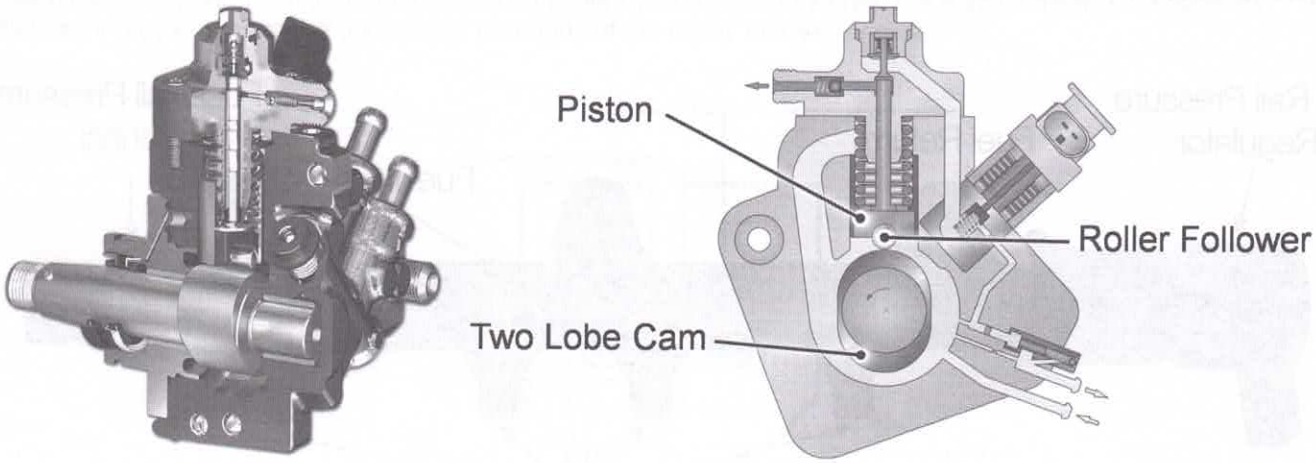


Figure 17: Continental two piston High Pressure Fuel Pump

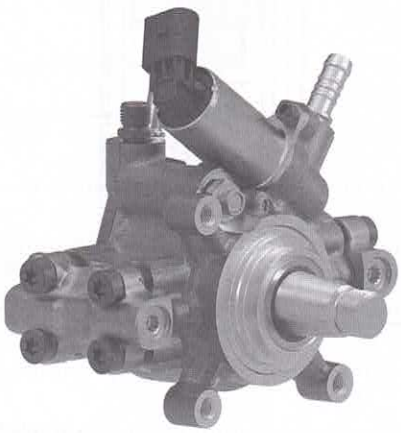
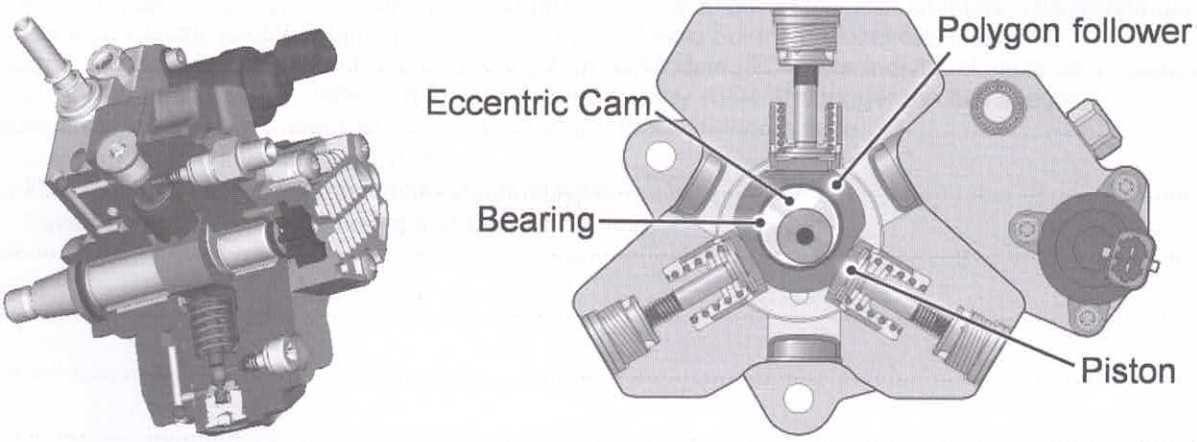


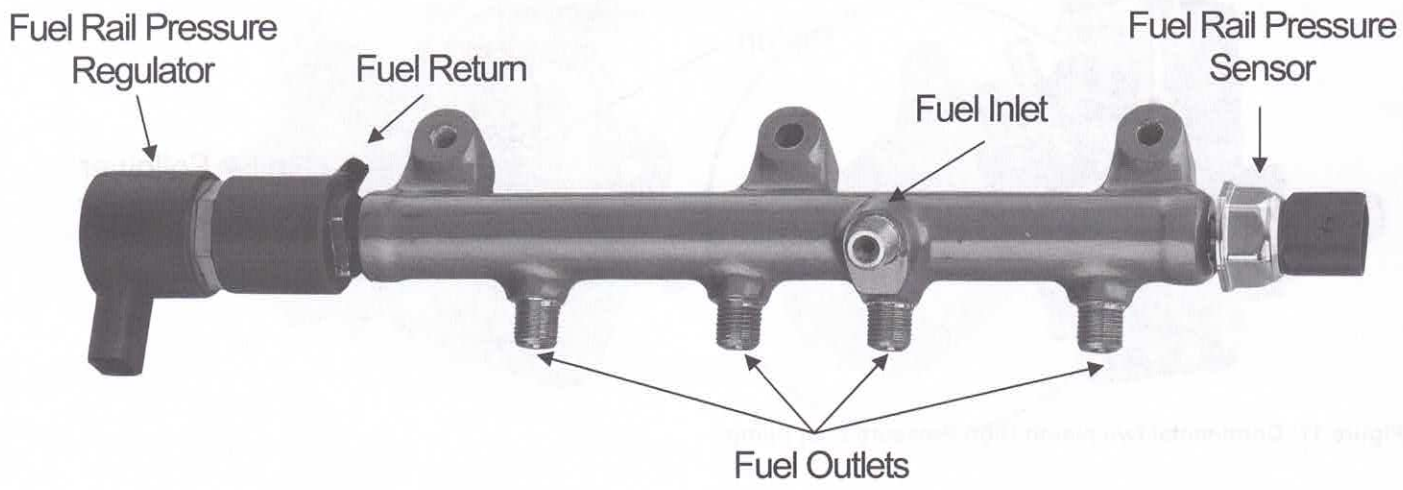
Figure 18: Bosch CP3 High Pressure Fuel Pump – As fitted to the 2008 Suzuki Grand Vitara



FUEL (COMMON) RAIL

Other than its obvious characteristic's of housing the Supply Pipe, Injector Pipes, Fuel Rail Pressure Regulator, Fuel Rail Pressure Sensor and the Fuel Limiting Valve (incorporated into Fuel Return in this example), a key attribute of the Fuel (Common) Rail is its dampening effect on the vibrations inherent in the fuel due to creation of pressure in the High Pressure Fuel Pump as well as from the opening and closing of the individual Fuel Injectors. It is because of these inherent vibrations in the fuel and the requirement of dampening that necessitates the High Pressure Fuel Pump to be timed to the engine.

Figure 19: Example of a typical Fuel (Common) Rail



FUEL INJECTORS

Currently, there are two types of Fuel Injectors used in CRD systems

1. Electro Solenoid
2. Piezo Electric

Electro Solenoid

Electro Solenoid diesel fuel injectors were the typical fitment for CRD systems that were built to run at EURO III. Their popularity dropped during EURO IV compliance and is scarce since the adoption of EURO V starting in 2010. These injectors perform well for up to 3 injections per cycle. Beyond this rate the Electro Solenoid diesel fuel injectors struggle to meet the operational demands of the highly efficient engines.

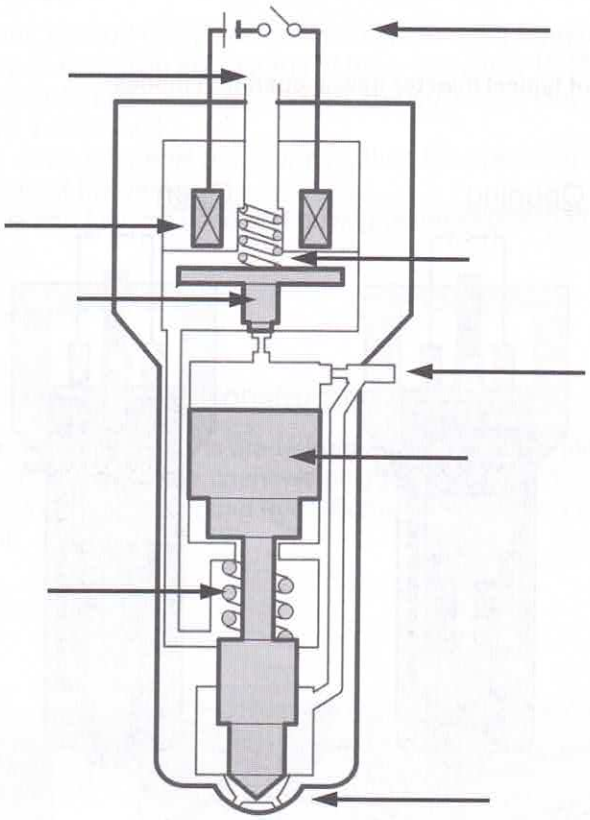


Figure 20: Schematic diagram of a typical injector

Piezo Electric

Piezo Electric diesel fuel injectors utilise a pack (approximately 400 discs) of Piezo Crystals. The nozzle design of a traditional Piezo Electric is of the same principle design as Electro Solenoid diesel fuel injectors.
When excited by an electrical pulse from the Engine Control Module (ECM) the individual piezo discs expand, collectively this creates enough deflection to actuate the auxiliary valve and trigger the fuel injection.
The benefits of Piezo Electric over Electro Solenoid diesel fuel injectors include:

- Used for up to 6 injection per cycle
- 75% less moving mass than electro solenoid type.
- Faster response = more efficient and cleaner running

FUEL INJECTORS continued...

Injector Nozzle

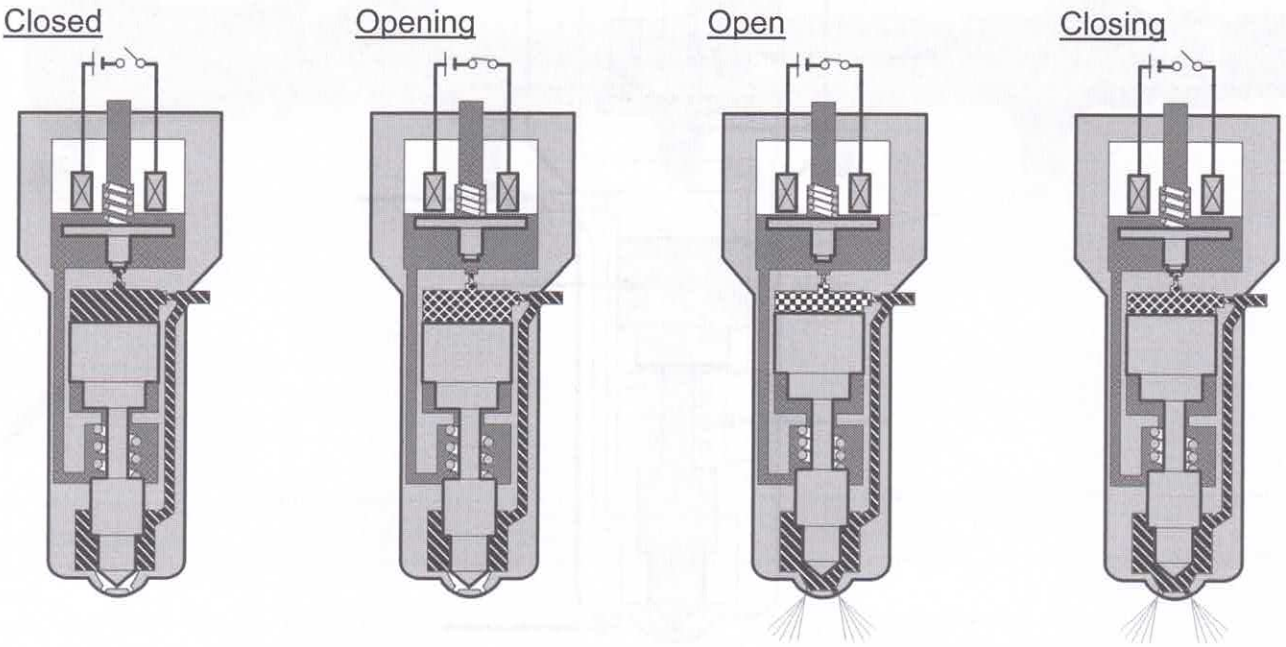
Both Electro-Solenoid and Piezo Electric injector types currently utilise indirect control of the fuel injection. Indirect control means that the electrical unit controlled by the Engine Control Module (ECM) controls an auxiliary valve within the Fuel Injector, this causes a pressure differential between the two ends of the injector needle.

Injector Nozzle operation

When the pressure at either end of the injector needle is equal the needle spring holds the nozzle closed. When the pressure behind the injector needle is lower than the nozzle pressure the injector needle is forced backward against the needle spring and the fuel is injected.

Quick Quiz

Figure 21: Schematic diagram of typical injector nozzle operation modes



Closed	Opening	Open	Closing
ECM command is: ON / OFF	ECM command is: ON / OFF	ECM command is: ON / OFF	ECM command is: ON / OFF
Aux. Valve is: OPEN / CLOSED	Aux. Valve is: OPEN / CLOSED	Aux. Valve is: OPEN / CLOSED	Aux. Valve is: OPEN / CLOSED
Pressure behind needle is: EQUAL / LOWER	Pressure behind needle is: EQUAL / LOWER	Pressure behind needle is: EQUAL / LOWER	Pressure behind needle is: EQUAL / LOWER
Needle is: OPENING / CLOSING / STILL	Needle is: OPENING / CLOSING / STILL	Needle is: OPENING / CLOSING / STILL	Needle is: OPENING / CLOSING / STILL
Inj. Nozzle is: OPEN / CLOSED	Inj. Nozzle is: OPEN / CLOSED	Inj. Nozzle is: OPEN / CLOSED	Inj. Nozzle is: OPEN / CLOSED

DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S)

Particulates or soot particles are the most visible of the pollutants emitted from the exhaust of a diesel engine. They consist of large carbon particles with other attached and absorbed chemicals. Particulates in addition to being visible are toxic and carcinogenic. The smaller particles of less than between 2.5 to 10 microns can readily penetrate deep into the lungs causing respiratory problems.

While there are many variations in the exact system designs,
there are essentially two main types of Diesel Exhaust After-Treatment (DEA):

1. Diesel Particulate Filters (DPF)
2. Select Catalyst Reduction (SCR)

Diesel Particulate Filters (DPF's)

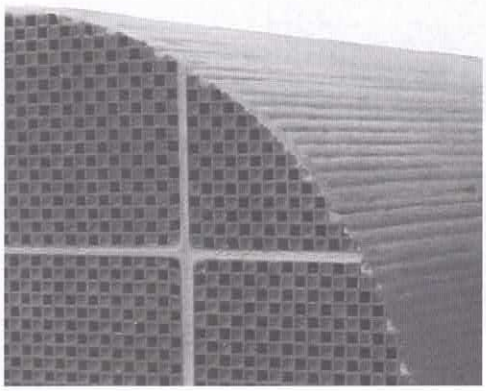
Diesel Particulate Filters are a common method used by manufacturers to meet Euro IV emissions on diesel vehicles. They have been used on road vehicles in some parts of the world since 1996. Carmakers estimate that DPF's remove between 85% and 100% of Particulate Matter (PM). Renault claim they reduce PM to below the measurable threshold of 5 mg/k (Euro 4 is 25 mg/k)
If the engine is in good condition and driving patterns are "normal", then the operation of the DPF will be invisible to the vehicle driver and it may last the life of the vehicle.
However, as engines age, incorrect oil and fuel are used and driving patterns change (short runs), problems will emerge that may require:

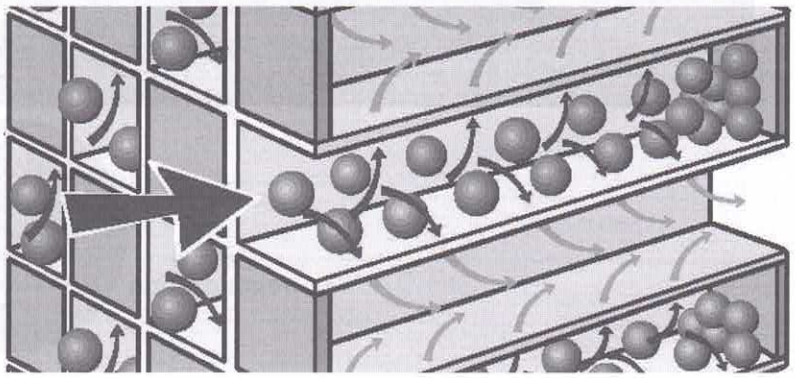
- A particular drive cycle
- Conducting a Service Regeneration
- DPF replacement

DPF Construction

The DPF core looks similar to a catalytic converter. It is made from a ceramic substrate; usually silicon carbide which has micro-porous walls. The core has alternate channels plugged which forces the gasses to flow through the wall and the particulates collect in the channel's "dead end". Some heavy vehicle DPF applications use a serviceable/replaceable filter element.

Figure 22 & 23: Typical DPF substrate





DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S) continued...

DPF Operation

The trapped Particulate Matter in the DPF is monitored by the ECM by means of a Pressure Differential Sensor which monitors the difference in exhaust gas pressure before and after the DPF. The pressure differential is calculated by the ECM and is usually displayed in the Live Data menu of a compatible Scan Tool in an inferred value of grams (g).
In most fitments, the use of an Oxidisation Catalyst upstream of the DPF is adopted. Unlike a 3 way catalyst such as those used on petrol vehicles, the Oxidisation Catalyst is a 2 way catalyst. Reducing Carbon Monoxide (CO) and Hydrocarbons (HC) but importantly for DPF operation it increases the exhaust gas temperature.
Once the exhaust gases have heated the DPF substrate (filter) to a temperature of 650°C to 800°C regeneration will occur.

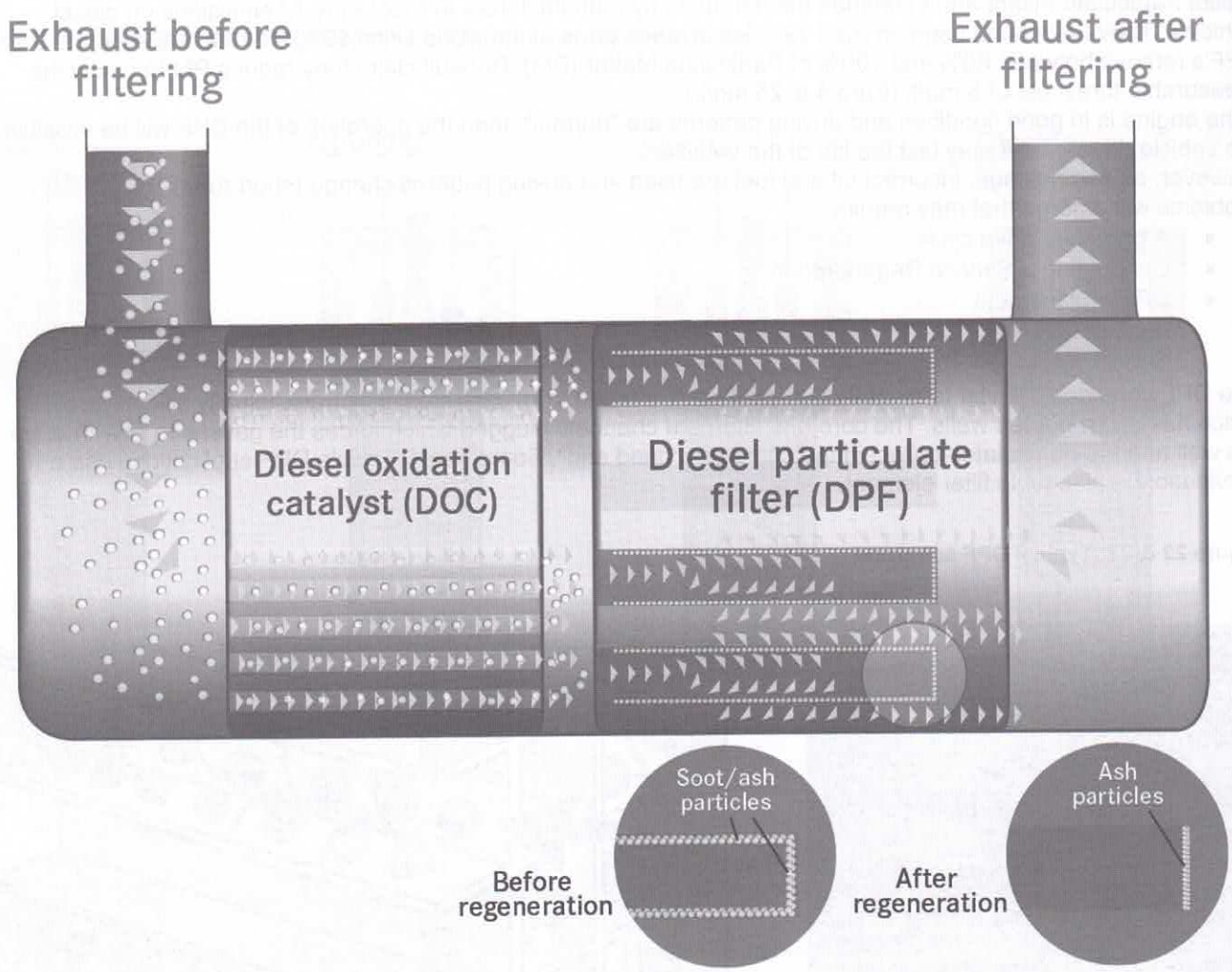


Figure 24: DPF operation schematic

DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S) continued...

Regeneration

Regeneration is the process of removing accumulated particles from the DPF.
While in regeneration mode the ECM will do any number of the following to achieve the desired exhaust temperature:

- Restrict throttle opening to facilitate enrichment
- Cease EGR operation to increase combustion temperature
- Delay main fuel injection to further facilitate enrichment
- Commence post fuel injection, fuel is vaporised but not burnt in the cylinder. This vapour oxidises in the Oxidisation Catalyst creating the 650°C to 800°C exhaust gas temperatures required for regeneration
- Adjust turbocharger operation (if fitted) to maintain typical engine performance
- Throughout all of the above the ECM monitors it's input signals to maintain efficient and thorough regeneration.

There are 4 ways in which regeneration can occur (names will vary slightly between manufacturers):

- Passive Regeneration
- Active Regeneration
- Driver Initiated Regeneration
- Service Regeneration

The type of regeneration that occurs depends on the amount of Particulate Matter (PM) trapped in the DPF and the operating conditions of the vehicle.

DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S) continued...

Passive Regeneration
Passive Regeneration occurs whenever the vehicles normal operation brings the DPF substrate up regeneration temperature (650°C to 800°C). In this operation there is no variation to vehicle operation and operator will be unaware that the regeneration has occurred.

Active Regeneration
For Active Regeneration to occur the amount of Particulate Matter trapped must be in the moderate range. Once the vehicle has completed all of the warm up criteria the ECM will use control the fuel delivery post injections to send unburnt fuel down the exhaust system to the Oxidisation Catalyst where it ignites and creates the exhaust gas heat required to initiate regeneration. The ECM may also adjust idle speed and alter automatic gearshift timing (where applicable) to keep the engine speed up.

Note: *Some manufacturers will program the ECM to perform an Active Regeneration at a specified distance regardless of the amount of Particulate Matter trapped. Typically the ECM initiates an Active Regeneration if a successful regeneration has not been completed in the previous 1,000km.*

Driver Initiated Regeneration
If the vehicle is not driven in a way that allows the DPF to regenerate fully the trapped Particulate Matter will eventually reach the full range. If this occurs the ECM will alert the driver usually through indicator lamps and/or LCD display in the Instrument Cluster. The Owner's Manual will set out a specific drive cycle for the driver to complete. This usually requires an extended drive at speeds in excess of 80km/h and may also require this to be done in a lower gear ratio.

Caution: *If the Driver Initiated Regeneration request is ignored it may result in a Service Regeneration, these usually incur a charge to the owner of the vehicle.*

Service Regeneration
If the driver fails to perform the Driver Initiated Regeneration and the trapped Particulate Matter continues to build up, the ECM will force the vehicle to undergo a Service Regeneration. The reason forcing the vehicle to return to a workshop for the procedure is because the level of contamination is so high, a partial regeneration may render the DPF unserviceable. As with the Driver Initiated Regeneration the driver will be alerted through indicator lamps and/or LCD display in the Instrument Cluster.

Caution: *If the ECM registers a DPF contamination level in excess of its threshold it will prevent the vehicle from undergoing any form of regeneration. This is for two main reasons: Firstly, the amount of contamination is so great that regeneration would be unlikely to return the DPF to a serviceable condition and secondly, the amount of back pressure in the exhaust coupled with the engine load required to achieve regeneration could result in catastrophic engine damage.*

Note: *In most cases, the manufacturer will require the engine oil and filter to be replaced after a Service Regeneration. Some vehicles actually increase the oil pan level by around half a litre due to dilution from the addition of extra fuel injected during the Service Regeneration process.*

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DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S) continued...

Selective Catalytic Reduction (SCR)

One of the problems associated with Diesel engines is that in order to improve efficiency; thereby improving engine power, lowering fuel consumption and reducing emissions of Particulate Matter, the by-product of the higher combustion temperatures is an increase in the emission of oxides of nitrogen (NO_X). Whilst High Pressure Exhaust Gas Recirculation has been used for many years to reduce NO_X, this method is no longer desirable as it works against the general efficiency of an engine and every loss must be recouped.

SCR is a relatively simple and relatively low cost technology to reduce NO_X in the exhaust pipe. It can yield reductions of up to 90%. The concept of SCR was patented in 1957 and has been developed and used in many industrial applications like stationary power plants and more recently ships, locomotives and motor vehicles.

Using SCR the engine can be optimised for higher power output, low particulate matter emissions and low fuel consumption. The reduction of NO_X is handled by after treatment in the exhaust pipe via the SCR catalyst. Most European truck makers are using SCR technology to meet Euro 4 and Euro 5 exhaust emission requirements. These same vehicles are also on the roads here in Australia, with increasing numbers being equipped with SCR systems. Mercedes-Benz has been using SCR under the banner of 'BLUETEC' engine technology. Another popular Australian passenger car to utilise the SCR technology is the Mazda CX-7 fitted with the MZR-CD engine. Interestingly other models in the Mazda range that utilise the MZR-CD engine do not require the SCR System.

Australian Emission Regulations

Australian Design Rule (ADR) 80/02 - Emission Control for Heavy Vehicles, (which equates to Euro 4) applies to all new vehicles sold from January 2008. This ADR required a reduction in NO_X by 30% and Particulate Matter by 80%.

Australian Design Rule (ADR) 80/03 - Emission Control for Heavy Vehicles, (which equates to Euro 5) applies to all new model vehicles from
January 2010 and all vehicles sold from January 2011. This ADR will require further 40% reduction in NO_X, but no further reductions in Particulate Matter.

Table 2: NO_X summary of ADR emissions

Standard	Introduction Date	NO_X Emission Limit (g/kWh)
ADR 80/00	2002/2003	5.0
ADR 80/01	2007/2008	3.5
ADR 80/02	2010/2011	2.0

NO_X Reducing Agent

SCR operation relies on a NO_X Reducing Agent (ammonia) which is injected into the exhaust prior to a special catalyst to transform NO_X molecules into nitrogen and water. Since ammonia is not the most suitable substance to be carrying around on vehicles, an "Aqueous Urea Solution" is used as the source of ammonia, The urea in the solution converts to ammonia when it is injected into the exhaust stream.

Aqueous Urea Solution

The Aqueous Urea Solution consists of approx. 32.5% Urea and 67.5% deionised / demineralised water. It is non-toxic, non-flammable, colourless, usually odourless and must be manufactured to meet the DIN 70070 standard.

One of the most common brands of urea solutions is a liquid marketed as "AdBlue". There is a growing network of AdBlue distributors around Australia. This began initially through truck dealerships and workshops and now includes tie ups with several national fuel companies. AdBlue say consumption (for trucks) is in the range of 0.4% by volume of diesel consumption for ADR 80/02 (Euro 4) vehicles and 0.6% by volume of diesel consumption for ADR 80/03 (Euro 5) vehicles.

DIESEL EXHAUST AFTER-TREATMENT'S (DEA'S) continued...

SCR System Layout

A tank contains the urea solution. A pump draws the urea solution from the tank and delivers it to the metering unit. The electronically controlled metering unit meters the urea solution into the mixer located in the exhaust stream. The SCR Catalyst is positioned downstream of the mixer.

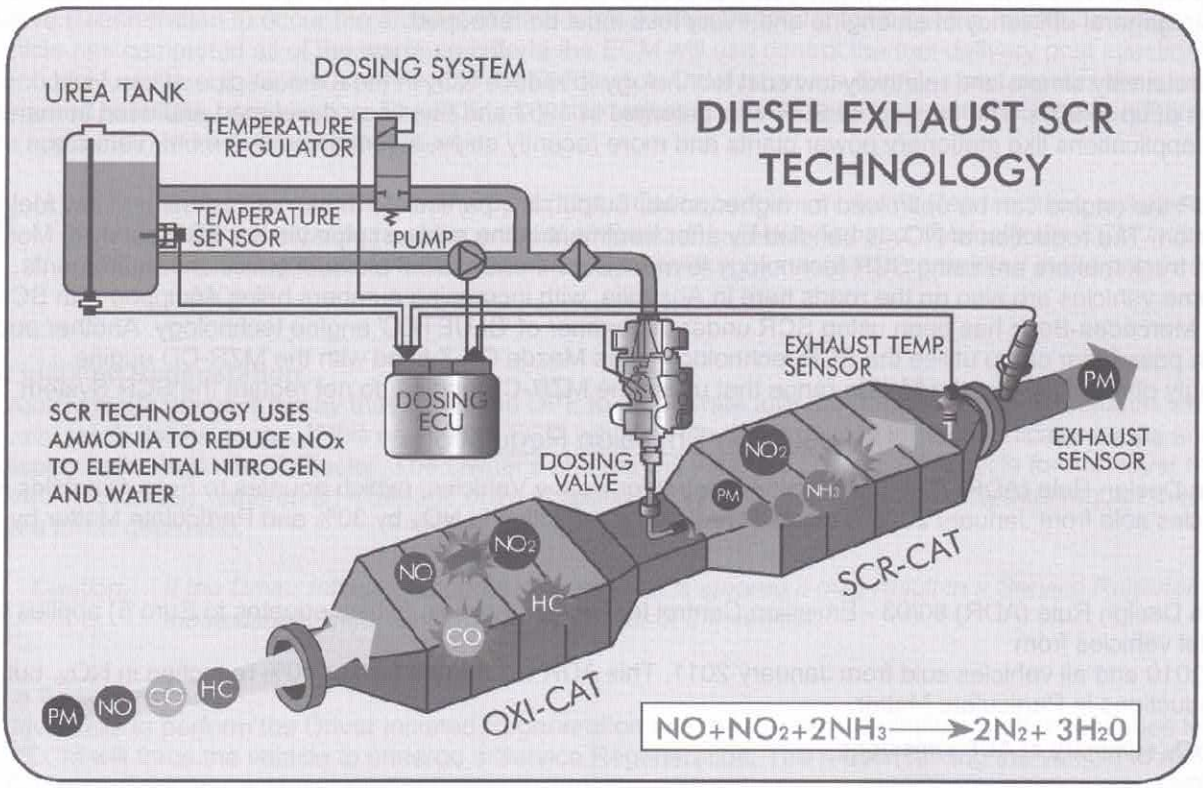


Figure 25: Typical SCR system layout

SCR System Operation

The metering unit injects the urea solution into the exhaust flow prior to the SCR Catalyst. The urea solution mixes with the exhaust gases where it is converted into ammonia. In the SCR Catalyst, the ammonia reacts with the NO_X, converting it to nitrogen and water.

If the urea solution tank is allowed to become empty or the incorrect specification liquid is used, the On Board Diagnostic (OBD) System will detect an increase in NO_X and will illuminate a warning lamp. If the NO_X is allowed to increase to approx. 5 g/kWh, the engine's ECM will record the data surrounding this event for later retrieval. If the fault remains and NO_X levels increase to twice the limit (7 g/kWh), the ECM applies a 40% power reduction strategy. The loss of power is enough incentive to have the vehicle condition rectified.

Mercedes-Benz has developed an AdBlue tank with a special filler neck that requires a dedicated nozzle to fill it. This ensures the tank does not get filled with diesel or petrol.

Apart from filling up the urea solution tank, there are generally no other significant servicing requirements for the SCR system. For best SCR efficiency, a low sulphur diesel fuel of less than 15ppm is required.

ENGINE OIL AND SERVICING

Engine Oil & Filter Replacement

It is of the utmost importance that the correct serving schedule is adhered to and that the correct filters and oil are used.

Note: *Use of the incorrect oil specification will eventually coat the Oxidation Catalyst and the DPF, reducing their service life. FOLLOW THE MANUFACTURERS OIL RECOMMENDATIONS CLOSELY.*

Some manufacturers require a reset of the service light and ECM system after an oil and filter change, in some cases this will require the use of a scan tool.

The correct oil for Common Rail Diesel engines to be able to work in conjunction with emission control devices and systems must be of a Low Sulphated Ash, Phosphorus and Sulphur levels.

Engine Oil Classifications

The International Lubricant Standardization and Approval Committee's (ILSAC) new GF-5 motor oil specification, is the current international standard and was phased in between October 2010 and September 2011. GF-5 motor oils are the most technologically advanced motor oil, exceeding the previous GF-4 category in a number of important performance areas.
ILSAC identified several major areas were manufacturers wanted to see improvement with the GF-5 category. These areas include:

- Fuel economy and fuel economy retention throughout the oil drain
- Emission-control systems protection
- Increased sludge, deposit and oxidation control
- Low-temperature viscosity,
- High and low-temperature corrosion
- Turbocharger protection
- Filter clogging protection

One of the highest priorities for engine oil manufacturers was making GF-5 motor oil backward compatible. Developing engine oil that is compatible for new and older engines helps prevent misapplications.

European Standard

Table 3: ACEA oil classification

ACEA - Association des Constructeurs Européens d'Automobiles (*in English: European Automobile Manufacturers Association*)		
Grade	Application	Classification/s
A/B	Oils suit most petrol and standard light diesel	A1/B1, A3/B3, A3/B4 and A5/B5
C	Oils suit Catalyst Engines. For use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low friction, low viscosity, low SAPS oils with a high HTHS. These oils will increase the DPF and TWC life and provide fuel economy benefit. *Caution:* *These oils have the lowest SAPS limits and may be unsuitable for use in some engines. Consult the Owner's Manual or handbook if in doubt.*	C1, C2, C3, C4 and C5

ENGINE OIL AND SERVICING continued...

American Standard

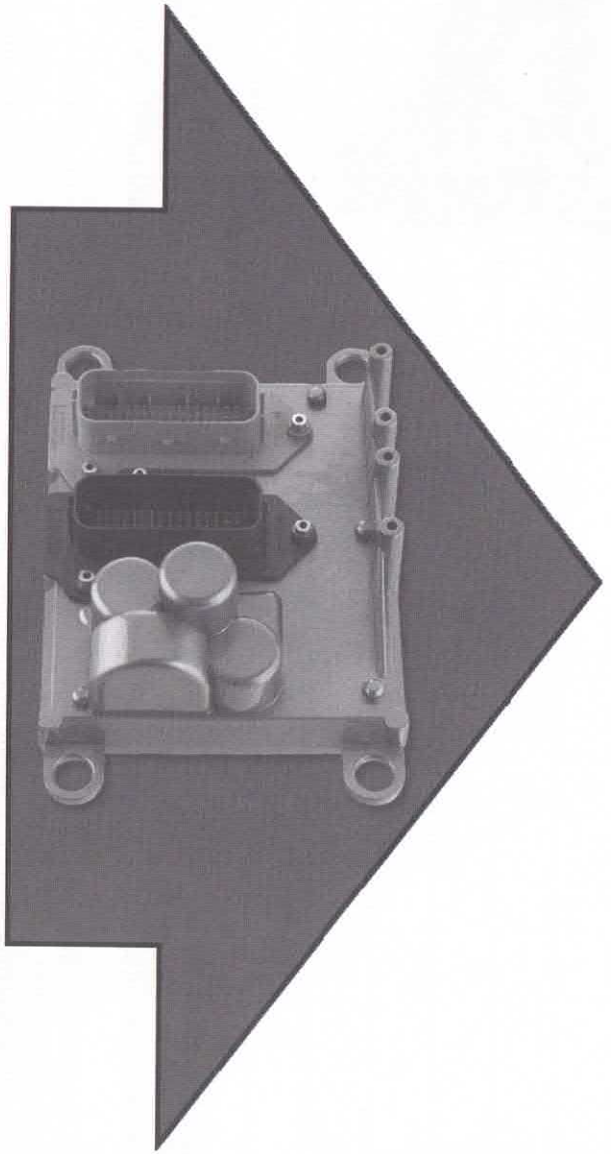
Table 4: API oil classification

API - American Petroleum Institute		
Grade	Application	Classification/s
S	Oils suit most petrol engines (S=Spark Ignition)	A1/B1, A3/B3, A3/B4 and A5/B5
C	Oils suit most pre 2002 diesel engines (C=Compression Ignition)	CI-4
	Oils suit most current diesel engines (C=Compression Ignition) except for those using a DPF. The PLUS indicates that the oil meets the CI-4 classification	CI-4 PLUS
	Oils suit Catalyst Engines (C=Compression Ignition). For use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low friction, low viscosity, low SAPS oils with a high HTHS. These oils will increase the DPF and TWC life and provide fuel economy benefit. *Caution: These oils have the lowest SAPS limits and may be unsuitable for use in some engines. Consult the Owner's Manual or handbook if in doubt.*	CJ-4

SAPS - Sulphated Ash, Phosphorus and Sulphur
DPF - Diesel Particulate Filter
TWC - Three Way Catalyst
HTHS - High temperature / High Shear rate viscosity
EGR - Exhaust Gas Recirculation

Inputs

Accelerator Pedal Position Sensors
Brake Position Switch
Camshaft Position Sensor
Clutch Position Switch
Crankshaft Position Sensor
Cylinder Pressure Sensors
Downstream Heated Oxygen Sensors
DPF Pressure Differential Sensor/s
EGR Temperature Sensor
EGR Valve Position Sensor
Engine Coolant Temperature Sensors
Exhaust Flap Position Sensor
Exhaust Gas Temperature Sensors
Exhaust Pressure Sensors
Fuel Pressure Sensor
Fuel Temperature Sensor
Intake Air Temperature Sensor
Intake Manifold Runner Control Position Sensor
Low Pressure EGR Pressure Sensor
Manifold Absolute Pressure Sensor
Mass Air Flow Sensor
Particulate Matter Sensor
Throttle Position Sensor
Turbocharger Actuator Position Sensor
Turbocharger Boost Pressure Sensor
Upstream Heated Oxygen Sensors



Actuators/Outputs

Auxiliary Pump
CAN BUS to various modules
DPF Indicator Lamp
Downstream Oxygen Sensor Heater
EGR Control Solenoids
Engine Coolant Circulation Pump
Exhaust Flap Control Motor
Fuel Injectors
Fuel Metering Valve
Fuel Pressure Regulator Valve
Fuel Pump Relay
Glow Plugs
Intake Manifold Runner Control Motor
Malfunction Indicator Lamp
SCR Control Unit
Throttle Control Motor
Transfer Pump
Turbocharger Wastegate Regulator
Upstream Oxygen Sensor Heater

Figure 26: Typical Common Rail Diesel – ECM Inputs & Outputs

CRD Technology

The Common Rail Diesel (CRD) system of today has evolved from its earliest incarnation developed in the late 1960's.
In this chapter we focus on a few key technological advances that will be further enhancing the operation of the CRD engine in the immediate future. These features are ultimately implemented to assist in reducing emissions even further, but most also result in enhanced engine performance and improved fuel efficiency.

DIRECT ACTING PIEZO ELECTRIC FUEL INJECTORS

As stated previously under the topic of Fuel Injectors in the CRD Components chapter, current Piezo Electric Fuel Injectors work on an indirect actuation. The following information and images were kindly supplied by Continental Automotive GmbH (formerly known as Siemens).
Direct Acting Piezo Electric Fuel Injectors utilise a direct mechanical link between the Piezo stack and the injector needle, reducing the hydraulic delay (also known as hydraulic dwell) to nil and reducing the overall injector response time to approximately $1/10^{th}$ that of regular (indirect) Piezo Injector response time. To achieve this, the Piezo stack is doubled in size from ≈400 to ≈800 layers.

Key Features and benefits include:

- More accurate injection
- Work at higher fuel pressure to increase atomisation
- Reduced leakage
- Can inject fuel up to 9 times per cycle
- As little as $0.3mm^3$ per injection
- Requires only 50 microseconds (µs) between injections
- Estimated to be in use by 2014

Continental Automotive GmbH also claim that the improved accuracy of the Direct Acting Piezo Electric Fuel Injectors over current Piezo Electric Fuel Injectors means the new engines have the potential of meeting EURO VI emission standard without the costly NO_X after-treatment.

Figure 27: Continental Automotive GmbH – Direct Acting Piezo Electric Fuel Injector

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IN-CYLINDER PRESSURE SENSORS

Another method for achieving low emissions is to allow for closed-loop Fuel Injector operation. This can be achieved by adopting In-Cylinder Pressure Sensors, a system adopted by VW in 2008 for the US market. While the VW components are designed and built by Bosch, the following information and images were kindly supplied by Continental Automotive GmbH (formerly known as Siemens).

The physical design of the In-Cylinder Pressure Sensor can be integrated into an otherwise typical Glow Plug or as a standalone sensor. The sensor tip (glow rod) is forced backward into the sensor housing by cylinder pressure sensor housing to a distance of up to 4mm. The movement is transferred to a diaphragm which has integrated strain gauges that convert the physical movement into and electrical signal that can be converted into a cylinder pressure value by the ECM.

Key Features and benefits include:

- Integration into Glow Plug means that physical changes to the Engine or Cylinder Head are not required
- Accurate to within 3.5%
- Allows for closed-loop combustion control

Figure 28: In-Cylinder Pressure Sensor - Integrated into Glow Plug

Figure 29: In-Cylinder Pressure Sensor – Stand alone

PARTICULATE MATTER SENSORS

Current Diesel Particulate Filter (DPF) Systems rely on measuring the differential pressure across the DPF to ascertain the contamination level and control regeneration. However, if the filter substrate were to fail and allow some of the exhaust gases to bypass the filter the ECM would not be able to sense that Particulate Matter (PM) was passing through and out of the tailpipe.
This challenge has led to the development of the Particulate Matter Sensor also known as a Soot Sensor.

The Particulate Matter Sensor uses a sample tube to draw exhaust gases from the centre of the exhaust stream into the sensing electrodes, downstream of the DPF.
As the exhaust gases travel along the sample tube PM that is evident in the gases is deposited on the sensing electrodes. The sensor works by measuring the resistance across the electrodes, as PM is deposited on the sensor the resistance decreases. The ECM monitors the PM build up is a set period of time, if the value exceeds its limits the ECM will log a Diagnostic Trouble Code (DTC). Once the sensing phase is completed the ECM will command sensor regeneration (burn-off cycle) to prepare the sensor for a new sensing phase.

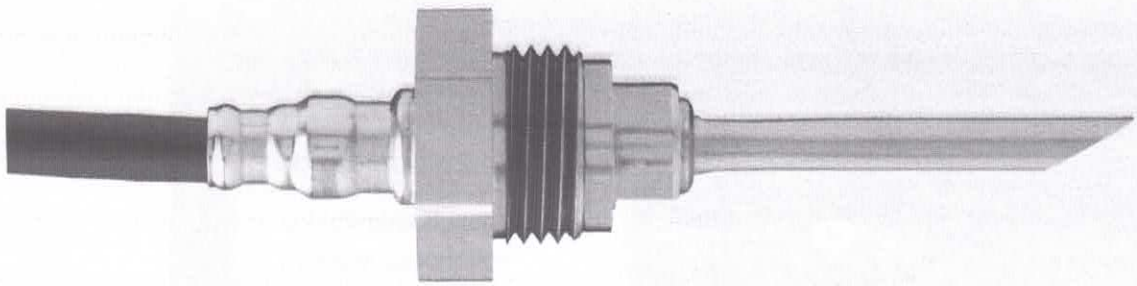

Figure 30: Delphi – Particulate Matter Sensor

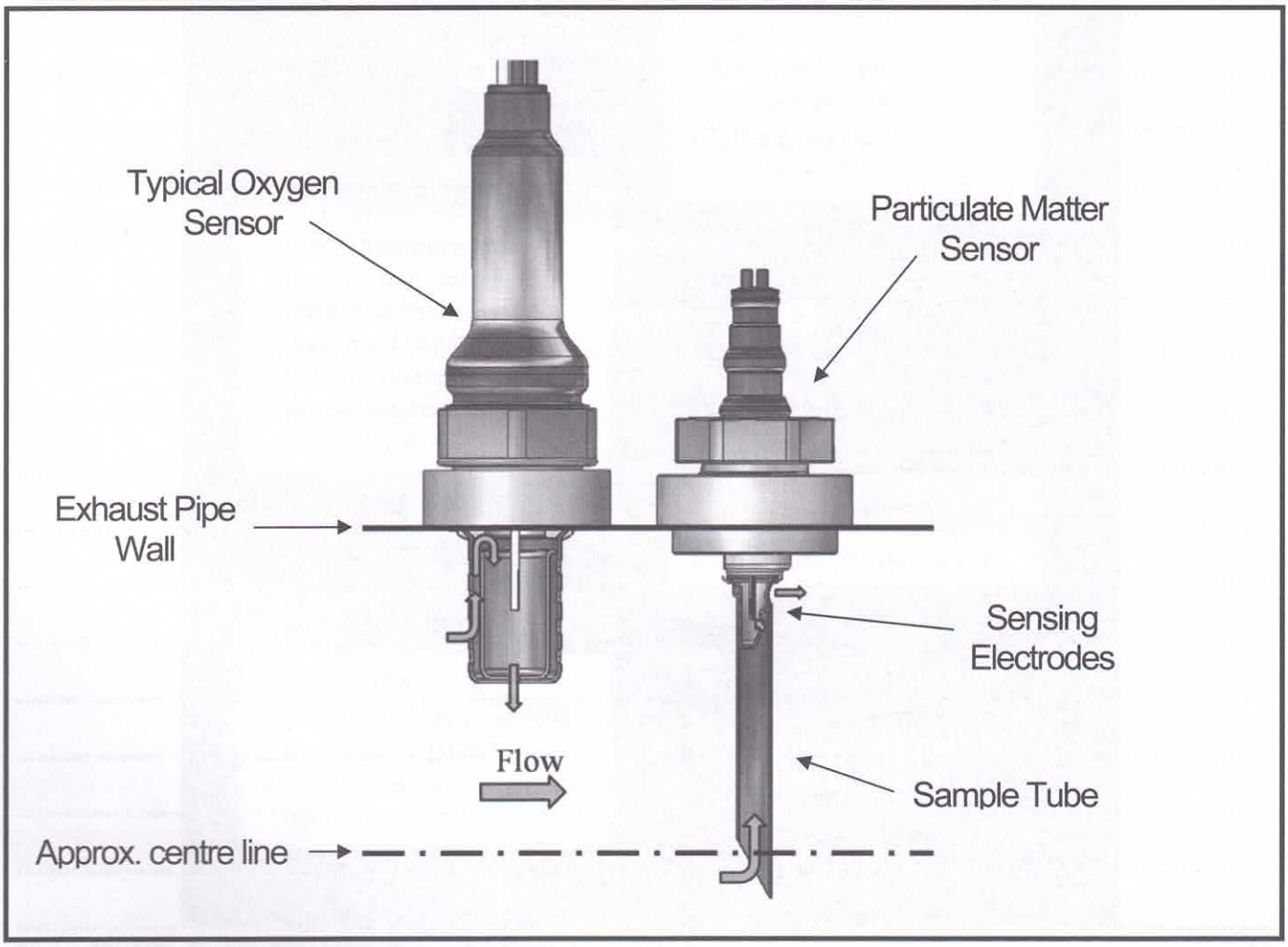

Figure 31: Delphi – Oxygen Sensor vs. Particulate Matter Sensor

CRD Diagnosis

In this chapter we investigate common diagnostic processes for a range of typical faults found on Common Rail Diesel vehicles. The diagnostic processes are of a generic nature and relevant to a variety of makes and models. It is important to note that these procedures should be used in conjunction with model specific information. To make these procedures relevant, a variety of common vehicles using CRD technology have been chosen to present each individual procedure.

- The diagnostic processes include:
- EGR & Intake System contamination
- Fuel System Bleeding
- Fuel Metering Valve – Malfunction
- Fuel Injector – Diagnosis & Coding
- DPF – Diagnosis & Regeneration

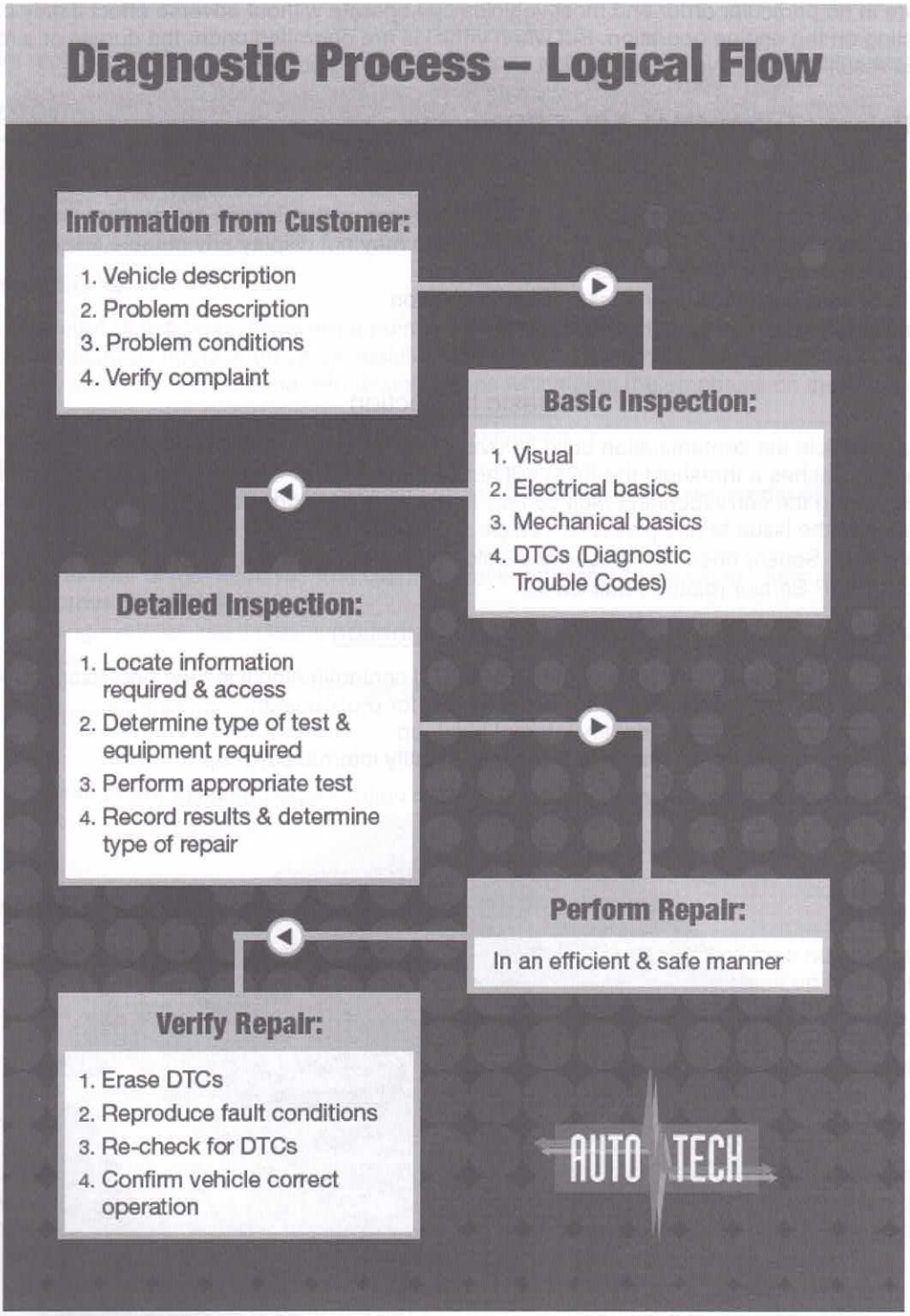

Figure 32: Auto-Tech's, Diagnostic Process – Logical Flow chart

EGR & INTAKE SYSTEM CONTAMINATION

EGR & Intake System contamination is arguably the largest issue affecting CRD engines, not only in Australia but globally. Most manufacturers are affected to varying degrees and for the most part these manufacturers are blaming poor quality fuels in Australia for their concerns. This is clearly not the case as a quick search of automotive forums around the world will show that these same contamination issues are rife in North America, South America, Africa, New Zealand, Japan, United Kingdom and Europe to name but a few!

The true cause of these issues is a combination of the following factors:

- Aggressive EGR to meet emission legislation
- Design flaws
- Fuel quality
- Environment & driving method
- Poor servicing

These points are in no particular order and most vehicles can operate without adverse effect if only one of the above is impacting on the engine operation. But when vehicles are operating under the duress of a multitude of these points the result is excessive contamination on a widely varying scale.

Mitsubishi Pajero / Triton 4M41 3.2L CRD engine

Fault Presentation

The way a vehicle suffering from excessive EGR & Intake System contamination will present depends on the severity of the concern, vehicles in the early stages of built up may not display any notable issues.
The following is a list of the likely complaints from the driver:

- Slight to Severe hesitation during takeoff & acceleration
- Poor fuel economy
- MIL may also illuminate.

Basic Inspection

For this particular vehicle the contamination build up eventually restricts the MAP sensor port. When the restriction to the MAP Sensor reaches a threshold the ECM will notice that the MAP Sensor is slow to respond to engine fluctuations and will log the corresponding fault codes. Two very quick inspections can help to identify that this is possibly the cause of the issue to any particular vehicle, these are:

- Remove MAP Sensor hose from Intake Manifold and check if port is restricted
- Check for MAP Sensor related Fault Codes

Detailed Inspection

If the basic inspection has shown evidence of Intake Manifold contamination it is then necessary to confirm categorically that the problem exists. There are two methods for proceeding:

1. Using a Borescope to visually identify internal build- up
2. Removal of the upper Intake Manifold to visually identify internal build- up

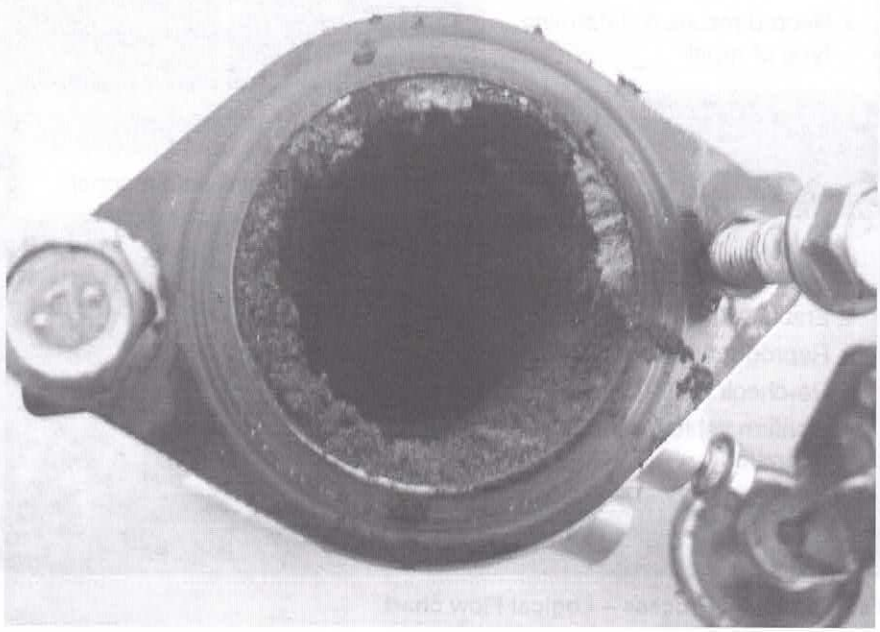

Figure 33: A typical example of carbon build-up in a Mitsubishi 4M41 Intake Manifold

EGR & INTAKE SYSTEM CONTAMINATION continued...

Perform the repair

Once it has been proven that there is sufficient build up to affect engine operation it will be necessary to decontaminate (clean) all of the affected components. The removal of the carbon build-up will correct the concern, however for the particular vehicle chosen in this procedure the manufacturer has a modified manifold available that moves the MAP Sensor port further upstream of the EGR port so that it does not get blocked by the build-up as quickly and therefore does not register MAP Sensor faults.

Note: *The modified Intake Manifold does nothing to address the cause of the manifold contamination. It just prolongs the time taken for the contamination to build up to the point where it will be evident to the driver.*

Verifying the repair

To verify that the repair carried out has addressed the customer's complaint, ensure the following steps are carried out:

1. Erase DTCs
2. Reproduce Fault Conditions
3. Re-check DTCs
4. Confirm Vehicle Operation

Preventative options

As mentioned at the start of this topic, there are a number of factors that work together to cause severe contamination. Addressing as many of these as possible will help to reduce build-up:

1. There is very little that can be done with design issues which puts the emphasis on the remaining contributors
2. Use only the highest quality fuels from reputable suppliers
3. Limit short trips and stop start driving environments
4. Ensure the vehicle receives adequate servicing (many CRD engine require interim oil and filter serving).

Additional options:

1. There are a number of fuel additives that claim to prevent this issue. However, there is no unbiased evidence to prove these claims
2. On car cleaning systems inject cleaning fluid into the Intake Manifold and are therefore quite effective

Note: *On car cleaning systems that use an electronic dosing unit ensure that only safe quantities of cleaning fluid are injected.*

Caution: *If the Driver Initiated Regeneration request is ignored it may result in a Service Regeneration, these usually incur a charge to the owner of the vehicle.*

How manufacturers are addressing this issue

Downstream NO_X traps and Select Catalyst Reduction (SCR) Systems are being used by a number of manufacturers but these are only used to reduce NO_X further and cannot be used to clean up NO_X from an engine that is not using EGR. The best answer currently available is the adoption of Low Pressure EGR.
Unlike High Pressure EGR that recirculates the exhaust gases before they enter the Turbo Charger and deposits them in the high pressure intake manifold (after the Turbocharger), Low Pressure EGR recirculates the exhaust gases after the Turbo Charger and DPF and deposits them in the air intake, upstream (low pressure/suction side) of the Turbo Charger turbine.

The use of Low Pressure EGR does not suit the varying operating conditions of an on road vehicle alone and therefore is only suitable for use in conjunction with High Pressure EGR. Because the Low Pressure EGR deposits the recycled gas upstream for the Turbo Charger turbine a filter is added to ensure that particles and contaminants do not damage the Turbo Charger or the Engine.

Note: *Low Pressure EGR is used in many EURO V compliant plant equipment where engine speed and load is NOT varied to large degrees or frequently.*

FUEL SYSTEM BLEEDING

When air enters a mechanical type Transfer Pump is has great difficulty in drawing fuel in as the design and tolerances do not allow for efficient suction of air. This means that many systems require manual air bleeding. The majority of CRD vehicles in Australia require some form of manual bleeding. Because there are so many variations for fuel system bleeding, this example uses a combination of bleeding requirements and is not focused on any one particular vehicle.

Air-lock diagnosis

Fault Presentation

Depending on the vehicle and the cause of air entering the fuel system, one or more of the symptoms may be evident. The following is a list of the likely complaints from the driver:

- Hard starting
- Unstable idle
- Engine runs for a short period before cutting out
- Lack of power/performance

As it is very difficult to identify air in the Fuel System it will help to identify if the customer has put the vehicle into a state that may have allowed this to occur. For example:

1. Run low or out of fuel
2. Replaced fuel filter
3. Drained off water separator (if fitted)
4. Disconnected any fuel lines

Because the Fuel System Bleed is fairly straight forward and there are no sight glasses or clear hoses fitted. Carrying out a bleed early in a diagnostic procedure is 'good practice' to rule out the possibility of an air-lock.

Inspection and Perform the Repair

In this procedure to complete the inspection is the same as carrying out the repair, justification of the procedure is firstly its simplicity and ultimately the correction of the fault. The procedure is as follows:
Connect bleeding pump using correct fittings and at the location identified by the manufacturer.
Pump fuel through the low pressure system until fuel free of air bubbles is evident.

Note: *Some vehicles have a Manual Bleeding Pump integrated into the fuel system, while some others utilise a scan tool to command an Electric Lift Pump ON and bleeding is done via a Schrader Valve (or similar).*

Warning: *Do NOT attempt to bleed the high pressure system. The high side is self bleeding.*

Verifying the repair

To verify that the repair carried out has addressed the customer's complaint, ensure the following steps are carried out:

1. Erase DTCs
2. Reproduce Fault Conditions
3. Re-check DTCs
4. Confirm Vehicle Operation

Note: *Air re-entering the system after bleeding indicates a leak in the low pressure fuel system.*

FUEL SYSTEM BLEEDING continued...

How manufacturers are addressing this issue

Electronic programs are implemented by some manufacturers to mimic fuel starvation in the form of a misfire and eventually shutdown the engine before the system can run dry. This is predominantly to reduce the risk of damage to the HP Fuel Pump through running dry (no fuel = no lube) and to prevent the need for Fuel System bleeding.

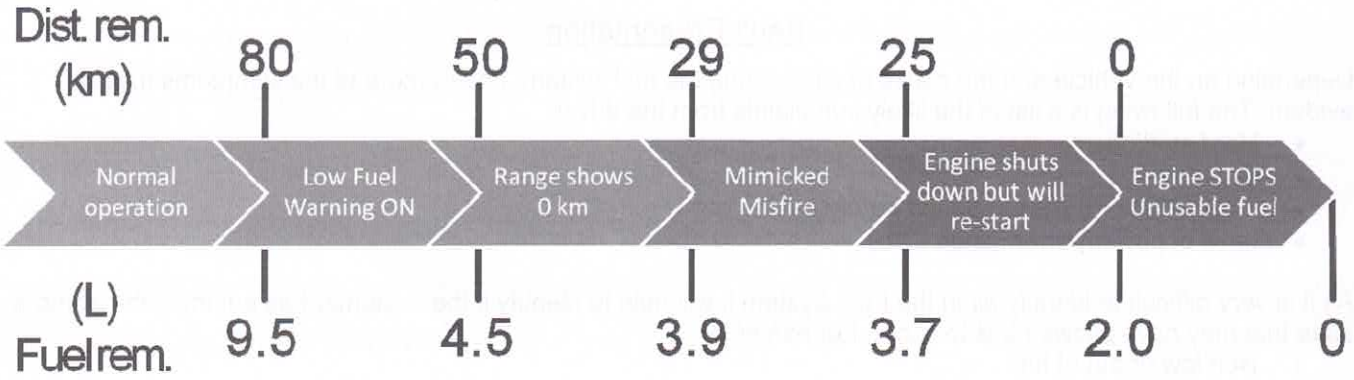

Figure 34: A typical example of the fuel protection system as found on some Citroen, Ford, Jaguar, Peugeot and Range Rover CRD engines. (Dist. Rem: refers to the in dash distance till empty value)

To cancel engine shutdown:

1. Add at least 5 litres of diesel to the fuel tank
2. To the Ignition ***'ON'*** for 20 seconds
3. To the Ignition ***'OFF'***
4. Repeat steps 2 & 3 two more times
5. The engine is now ready to be started.

Caution: *If unleaded petrol is added to the fuel tank DO NOT start the engine. Even small amounts of fuel reduce the lubricity of the diesel fuel and can lead to catastrophic High Pressure Pump and in some cases Engine failure.*

Note: *If the engine has been started it makes flushing and bleeding considerably harder and in most cases will VOID the warranty on the HP Fuel Pump and related components.*

FUEL METERING VALVE - MALFUNCTION

The Fuel Metering Valve (and its aliases) is the only 'actuated' component on/in the Fuel Delivery Pump and for Single Pressure Control Systems it is the sole fuel pressure control device. It is also one of the most likely components in the CRD fuel system to fault.
To put the Fuel Metering System into context we'll use the Isuzu/Holden 4JJ1 CRD engine as a reference. This particular engine was chosen because of its popularity and evidence that suggest that they are susceptible to this issue.

Isuzu/Holden 4JJ1 3.0L CRD engine

Fault Presentation

The following is a list of the likely complaints from the driver:

- Lack of power during takeoff & acceleration
- Hard starting
- MIL illuminated.

Basic Inspection

To confirm this malfunction it will need to be identified that the fuel amount being delivered is less than the amount commended by the ECM.

1. Check underbody of vehicle for damaged fuel lines
2. Check for Fault Codes

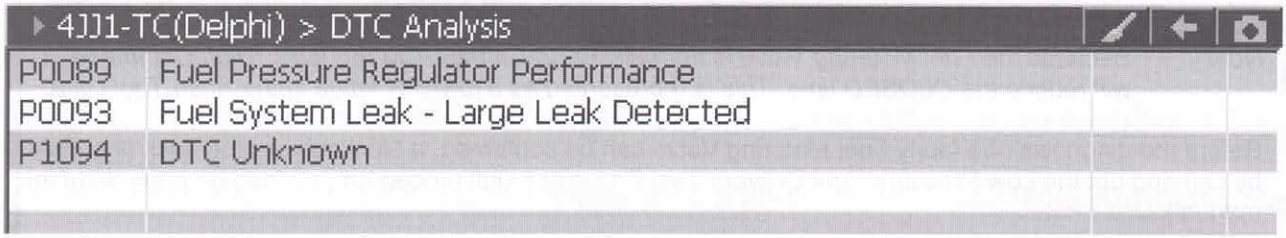
4JJ1-TC(Delphi) > DTC Analysis
P0089 Fuel Pressure Regulator Performance
P0093 Fuel System Leak - Large Leak Detected
P1094 DTC Unknown

Figure 35: DTC output from 2008 Holden Colorado (4JJ1 eng.) with a faulty Fuel Metering Valve

Note: DTC P1094 = Fuel Rail Pressure Regulator – High command and low rail pressure.

FUEL METERING VALVE - MALFUNCTION continued...

Detailed Inspection

If the basic inspection found damage to the Fuel Lines then these must be addressed first, then clear codes and retest. If no evidence of damage is evident and one or more of the codes shown in *Figure 36* are logged, continue as follows (*see also Scan Tool Data table on page 39 of this manual*):

1. Access the live data using a compatible scan tool
2. Shuffle data so that the following parameters are visible simultaneously:
   - Desired Fuel Rail Pressure (should be 30MPa @ Idle & >70MPa @2,000 rpm)
   - Fuel Rail Pressure (should be 27-33MPa @ Idle & >70MPa @2,000 rpm)
   - Fuel Rail Pressure Regulator command (should be 35-50%)
3. Monitor the data while the fault is evident

4JJ1-TC(Delphi) > Data Analysis(Select Item)

Item	Value	Unit	Min	Max
Engne speed	861	rpm	696	1027
Desired fuel rail pressure	41	MPa	30	42
Fuel rail pressure	9	MPa	8	32
FRP regulator command	15	%	15	18

Figure 36: Data output from 2008 Holden Colorado (4JJ1 eng.) with a faulty Fuel Metering Valve

Note: *Because the Fuel Metering Valve is normally OPEN, if the PCM requests "High Command" it will reduce the CLOSED time. This is represented as a lower % value in the Scan Tool Data.*

4. Before the diagnosis of a faulty Fuel Metering Valve can be confirmed, a blockage or other lack of supply by carrying out the Low Pressure Fuel Delivery Test Procedure (full procedure provided on *page 40* of this manual).

Perform the repair

If the Low Pressure Fuel Delivery Test Procedure confirms that the fuel delivery up to the High Pressure Fuel Pump is within specifications, replacement of the Fuel Metering Valve is required as follows:

1. Replace the Fuel Rail Pressure Regulator (also referred to as the Suction Control Valve) with the revised component
   (P/N 8981454530 correct at time of publishing 05/2012)
2. Replace the Fuel Filter
3. Bleed the Fuel System (full procedure provided on *page 41* of this manual)
4. Carry out High Pressure Fuel Pump Relearn (full procedure provided on *page 41* of this manual)

Caution: *These are 3 very important steps:*

1. *Even though the revised Fuel Pressure Regulator has been designed to overcome this vulnerability, the cause of failure is that foreign matter has jammed the pintle. For this reason replacement of the Fuel Filter is advised*
2. *Bleed air to ensure that all air-locks are purged*
3. *The relearn "fine tunes" the Fuel Metering Valve and allows the PCM to adapt to all of the physical characteristics of the High Pressure Fuel Pump.*

Verifying the repair

To verify that the repair carried out has addressed the customer's complaint, ensure the following steps are carried out:

1. Erase DTCs
2. Reproduce Fault Conditions
3. Re-check DTCs
4. Confirm Vehicle Operation

FUEL METERING VALVE - MALFUNCTION continued...

Vehicle	HOLDEN COLORADO 4JJ1TC DOHC 16v TURBO DIESEL DI 4cyl 3.0L 5sp Man Space Cab CH 4x4 [07/08 - 12/08]
Category	Electronic Systems

Scan Tool Data

Scan Tool Data

Scan Tools with suitable functionality will be able to monitor 'Live Values'.

The number of these items detectable with a Scan Tool depends on its coding.

Not all of these items will be available on all Scan Tools.

Vehicle MUST be @ Normal Operation Temperature with A/C and other loads OFF before checking values unless otherwise stated.

Parameter	Status	Value
Desired Fuel Rail Pressure (MPa)	Engine Idling	30 MPa
	Engine @ 2,000 RPM	More than 70 MPa
Fuel Rail Pressure (MPa)	Engine Idling	27 to 33 MPa
	Engine @ 2,000 RPM	More than 70 MPa
Fuel Rail Pressure (Volts)	Engine Idling	1.4 to 1.5 Volts
	Engine @ 2,000 RPM	More than 2.1 Volts
Fuel Rail Pressure (FRP) Regulator Command	Engine Idling	35 to 50%
	Engine @ 2,000 RPM	35 to 45%
Fuel Rail Pressure (FRP) Regulator Flow	Engine Idling	More than 1,000 mm3/sec
	Engine @ 2,000 RPM	More than 2,000 mm3/sec

Figure 37: Scan Tool Data specifications for 2008 Holden Colorado (4JJ1 eng.) from Autopedia

FUEL METERING VALVE - MALFUNCTION continued...

Vehicle	HOLDEN COLORADO 4JJ1TC DOHC 16v TURBO DIESEL DI 4cyl 3.0L 5sp Man Space Cab CH 4x4 [07/08 - 12/08]
Category	Electronic Systems

Fuel System

Fuel System

Low Pressure Fuel Delivery Test Procedure

The Low Pressure Fuel Delivery Test Procedure is used to establish wether the High Pressure Fuel Pump is receiving sufficient fuel quantity with which to control the engine.

The procedure is conducted as follows:

1. Ignition OFF
2. Connect a compatible Scan Tool
3. Disconnect the inlet hose from the High Pressure Fuel Pump
4. Direct the inlet hose into a measured flask
5. Turn the Ignition ON (DO NOT start the engine)
6. Using the Actuation feature on the Scan Tool, actuate the Fuel Pump
7. For each 20 Seconds of Fuel Pump on-time 100ml of fuel should be delivered
8. Run the Fuel Pump for a total of 2 minutes (6 x 20 Seconds) and confirm that at least 600ml of fuel is delivered

Was ≥ 600ml of fuel delivered?

NO: Carry out the same test at the Fuel Pump outlet on the top of Fuel Tank.

YES: Replace the Fuel Rail Pressure Regulator

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Figure 38: Low Pressure Fuel Delivery Test Procedure for 2008 Holden Colorado (4JJ1 eng.) from Autopedia

FUEL METERING VALVE - MALFUNCTION continued...

Vehicle	HOLDEN COLORADO 4JJ1TC DOHC 16v TURBO DIESEL DI 4cyl 3.0L 5sp Man Space Cab CH 4x4 [07/08 - 12/08]
Category	Electronic Systems

Fuel System

Fuel System

Fuel System Air Bleeding Procedure

The Fuel System Air Bleeding Procedure MUST be carried out whenever the fuel system has be opened between the Low Pressure Fuel Pump in the Fuel Tank and the High Pressure Fuel Pump on the Engine.
It MUST also be carried out after completing the Fuel System Water Bleeding Procedure.

1. Start with the Ignition Switch OFF
2. Turn the Ignition Switch ON for 15 Seconds
3. Turn the Ignition Switch OFF
4. Repeat steps 2 and 3 five times
5. Start the Engine and allow it to idle for 10 minutes
6. Check that there are no fuel leaks
7. The procedure is now completed.

High Pressure Fuel Pump Relearn Procedure

The High Pressure Fuel Pump Relearn Procedure is used to calibrate the Fuel Rail Pressure Regulator after any of the following components are replaced:

- ECM
- High Pressure Fuel Pump
- Fuel Rail Pressure Regulator

The procedure must be carried out with a compatible Scan Tool as follows:

1. Ignition OFF
2. Connect a compatible Scan Tool
3. Turn the Ignition ON (DO NOT start the engine)
4. Using the Scan Tool, initiate the Supply Pump Learn Reset
5. The Supply Pump Status (in the Scan Tool Data table) should now display NOT LEARNED
6. Start the engine and allow it to idle until the coolant temp exceeds 65°C
7. The Supply Pump Status should progress to LEARNING and then LEARNED
8. After this point the Supply Pump Status should switch between LEARNING and LEARNED continuously
9. Switch the Ignition OFF and remove the Scan Tool.

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Figure 39: Bleeding and Relearn Procedures for 2008 Holden Colorado (4JJ1 eng.) from Autopedia

FUEL INJECTOR – DIAGNOSIS & CODING

By far, the vast majority of CRD systems require injectors to be coded to the PCM. Typically referred to as "Compensation Coding" it allows the minute variations in physical characteristics to be allowed for. Meaning that regardless of these variations the PCM will compensate and achieve accurate fuel delivery. The Injectors are checked and measured at the place of production and assigned a code that describes its physical characteristics. The Injector Compensation Code is identified by an alphanumeric code.
Figure 40 below illustrates a Bosch 7-digit alphanumeric sequence and a Denso 30-digit alphanumeric sequence.

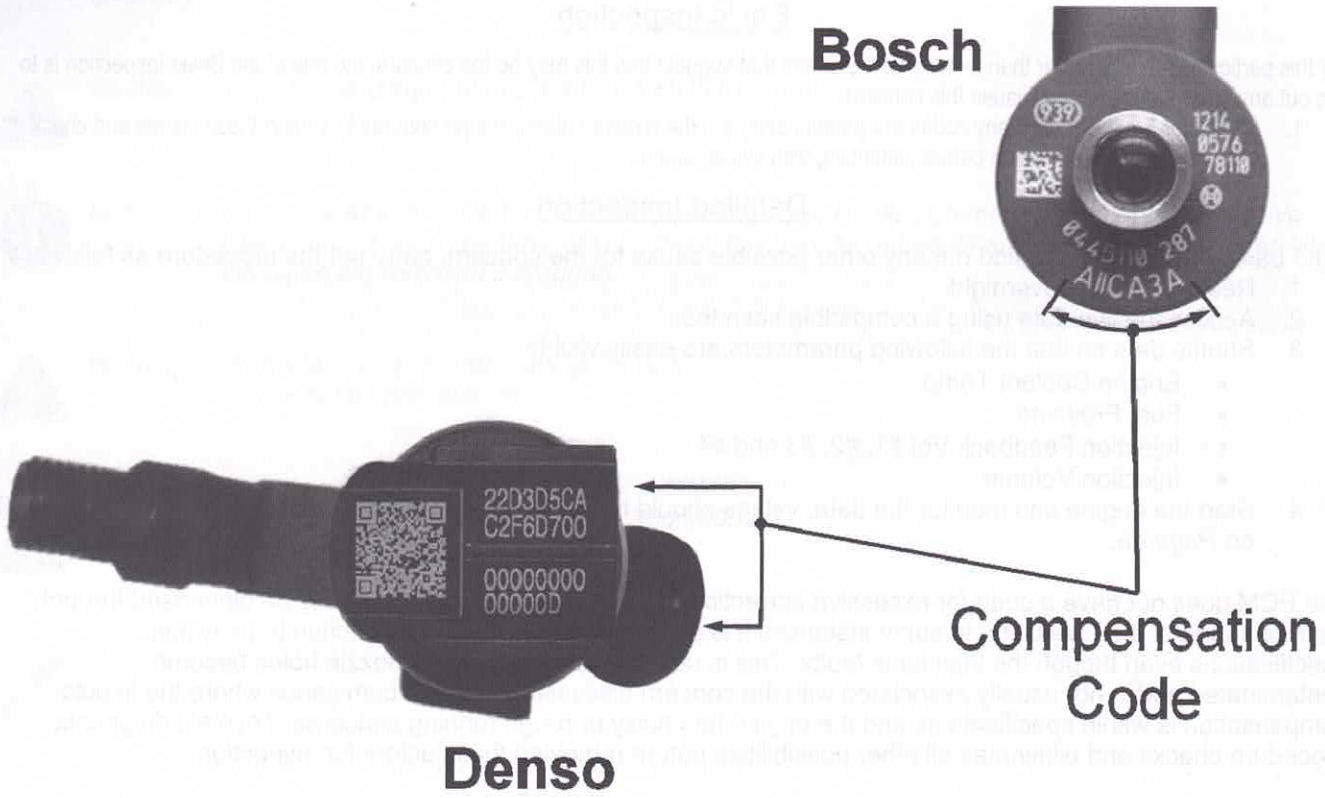


Figure 40: Example of Bosch and Denso Compensation Codes

Note: *QR Codes are an alternative to a barcode that can carry significantly more information in a smaller space. These are used only for production purposes and hold the same information as that alphanumeric code.*

The Injector Compensation Code is based on identifying key operating parameters and measuring those parameters from a specification, this is the variation from specification and is what the PCM must compensate for. To create their compensation code Denso identifies the 12 correction points that it uses in each of its 30-digit sequences. It identifies what Actuating Pulse Width is required to deliver a set amount of fuel (Injection Quantity) at 5 different pressures.

Using compensation codes not only improves the accuracy of the PCM control, but also allows manufacturers to broaden the tolerances of manufacture. This reduces manufacturing costs. To put the Fuel Injector diagnosis & coding into context we'll use the Toyota 1KD CRD engine as a reference. This particular engine was chosen because of its popularity and evidence that suggest that they are susceptible to this issue.

FUEL INJECTOR – DIAGNOSIS & CODING continued...

Toyota Prado / Hilux 1KD-FTV 3.0L CRD engine

Fault Presentation

The driver will notice that the vehicle is dieseling (rattling) excessively, immediately after cold start-up. It starts as a cold start only issue, over time that noise level increases and eventually it will rattle continuously (however, this is quite rare because the noise level at cold start is so extreme that most find it unbearable).

Basic Inspection

For this particular concern rather than looking for indicators that suggest that this may be the concern, the role of the Basic Inspection is to rule out any other faults that may cause this concern.

1. Check for Fault Codes, if any codes are present carry out the required diagnostic procedures to correct these issues and check that the condition still exists before continuing with this procedure.

Detailed Inspection

If the basic inspection has ruled out any other possible cause for the concern, carry out the procedure as follows:

1. Rest the vehicle overnight
2. Access the live data using a compatible scan tool
3. Shuffle data so that the following parameters are easily visible:
   - Engine Coolant Temp
   - Fuel Pressure
   - Injection Feedback Vol #1, #2, #3 and #4
   - Injection Volume
4. Start the engine and monitor the data, values should be between the values shown in the table of *Figure 47* on *Page 46*.

The PCM does not have a code for excessive correction, if the problem occurs it can only be diagnosed through the monitoring of the Live Data. In some instances it is possible for the injection correction to be within specifications even though the injector is faulty. This is usually caused when the nozzle holes become contaminated and is not usually associated with the concern discussed. In the circumstance where the injector compensation is within specifications and the engine has noisy or rough running concerns, Toyota's diagnostic procedure checks and eliminates all other possibilities before removing the injectors for inspection.

Note: *Toyota's diagnostic procedure states that if contamination is found on one injector the remaining injectors should be removed for inspection. However, dismantling of the injector to inspect requires specialised equipment and as they are non-serviceable (due to the compensation code) eventuates in injector replacement. Therefore the recommendation is to replace all injectors if one is deemed to be faulty.*

FUEL INJECTOR – DIAGNOSIS & CODING continued...

Perform the repair

1. Fit the injectors as per the correct procedure
2. Assign the correct compensation codes with a compatible Scan Tool. The 30-digit alphanumeric codes must be programmed into the ECM. The QR Code to the right is only used in manufacture and cannot used by dealers or other repairers. However, some Scan Tools may have the ability of reading the code from the Fuel Injector directly. (*Figures 41 to 46* on the following page show the procedure as carried out with a G-Scan)

Caution: *Toyota states that the Injector Pipes MUST be replaced.*

Note: *As you need to remove the Injector Pipes to get the Rocker Cover OFF and adjust the valve clearances, it would be advisable to check the Service Schedule and inspect/adjust valves while the pipes are removed if required.*

Warning: *High Voltage up to 150 Volts @ 25 Amps (follow safety precautions).*

Warning: *Extremely high fuel pressure up to 200,000 kPa (follow safety precautions).*

FUEL INJECTOR – DIAGNOSIS & CODING continued...

Figure 41:Toyota Injection Compensation Coding Procedure – Sten #1

TCCS(Engine AT) > Injector Compensation
This function is used to set the compensation code for the new injector assembly or the injectors to the engine ECU when replacing the injector assembly or the injectors.
This function must not be operated without referring the service manual.
Ok
Cancel

Figure 42: Toyota Injection Compensation Coding Procedure – Sten #2

Figure 43: Toyota Injection Compensation Coding Procedure – Sten #3

Figure 44: Toyota Injection Compensation Coding Procedure – Sten #4

Figure 45: Toyota Injection Compensation Coding Procedure – Sten #5

Figure 46: Toyota Injection Compensation Coding Procedure – Sten #6

Caution: *If the Fuel Injectors are replaced without updating the compensation codes*

a. *Engine may rattle, blow smoke and use excessive amount of fuel until the PCM re-learns its own correction values.*
b. *Future diagnostics will be severely diminished because it is likely that Injection Quantity Corrections will be outside of parameters just to achieve normal operation.*
c. *Always check that the codes logged into the PCM match those on the top of the Injectors.*

FUEL INJECTOR – DIAGNOSIS & CODING continued...

Verifying the repair

To verify that the repair carried out has addressed the customer's complaint, ensure the following steps are carried out:

1. Erase DTCs
2. Reproduce Fault Conditions
3. Re-check DTCs
4. Confirm Vehicle Operation

Vehicle	TOYOTA LANDCRUISER PRADO KDJ120R 1KD-TE DOHC 16v TURBO DIESEL 4cyl 3.0L 5sp Auto 4D Wagon AWD [11/06 - 12/09]
Category	Electronic Systems

Fuel System

+ Fuel System

− Scan Tool Data

Scan Tools with suitable functionality will be able to monitor 'Live Values'.

The number of these items detectable with a Scan Tool depends on its coding.

Not all of these items will be available on all Scan Tools.

Vehicle MUST be @ Normal Operation Temperature with A/C and other loads OFF before checking values unless otherwise stated.

Parameter	Status	Value
Engine Coolant Temp (Coolant Temp)	Engine Idling	80 to 95°C
Fuel Pressure (Fuel Press)	Engine Idling	30,000 to 40,000 kPa
Initial Engine Coolant Temp (Ini Cool Temp)	Engine Idling	Engine coolant temp @ start up
Injection Feedback Value (Inj Fb Val)	Engine Idling	-4 to 4 mm3
Injection Feedback Value #1 (Inj Fb Val #1)	Engine Idling	-3 to 3 mm3
Injection Feedback Value #2 (Inj Fb Val #1)	Engine Idling	-3 to 3 mm3
Injection Feedback Value #3 (Inj Fb Val #1)	Engine Idling	-3 to 3 mm3
Injection Feedback Value #4 (Inj Fb Val #1)	Engine Idling	-3 to 3 mm3
Injection Pressure Correction (Inj Press FB Val)	Varies	-400 to 400 mm3 per stroke
Injection Volume (Inj Vol)	Engine Idling	3 to 12 mm3
Target Fuel / Common Rail Pressure (Tag Comm Rail Press)	Engine Idling	30,000 to 40,000 kPa

Figure 47: Scan Tool Data specifications for 2006-09 Toyota Prado (1KD-FTV eng.) from Autopedia

DPF – DIAGNOSIS & REGENERATION

Diesel Particulate Filter's (DPF's) for part of Diesel Exhaust After-treatment (DEA) System which was covered on *Pages 19 to 21* in the CRD Components chapter of this manual. To highlight how the DPF System works the following pages will discuss the Diagnosis & Regeneration principles of the VAG (Volkswagen Auto Group) and Mazda MZR-CD systems.

VAG (Volkswagen Auto Group)

The system described below has been written from a variety of data resources and is typical to a range of VAG engines. These can be found under manufacturer labels such as VW, Audi, Seat & Skoda and are typically in 1.6L and 2.0L capacities. It covers vehicles made in the 2010 to 2012 Model Years (MY) and is usually badged as TDI (turbocharged Direct Injection).

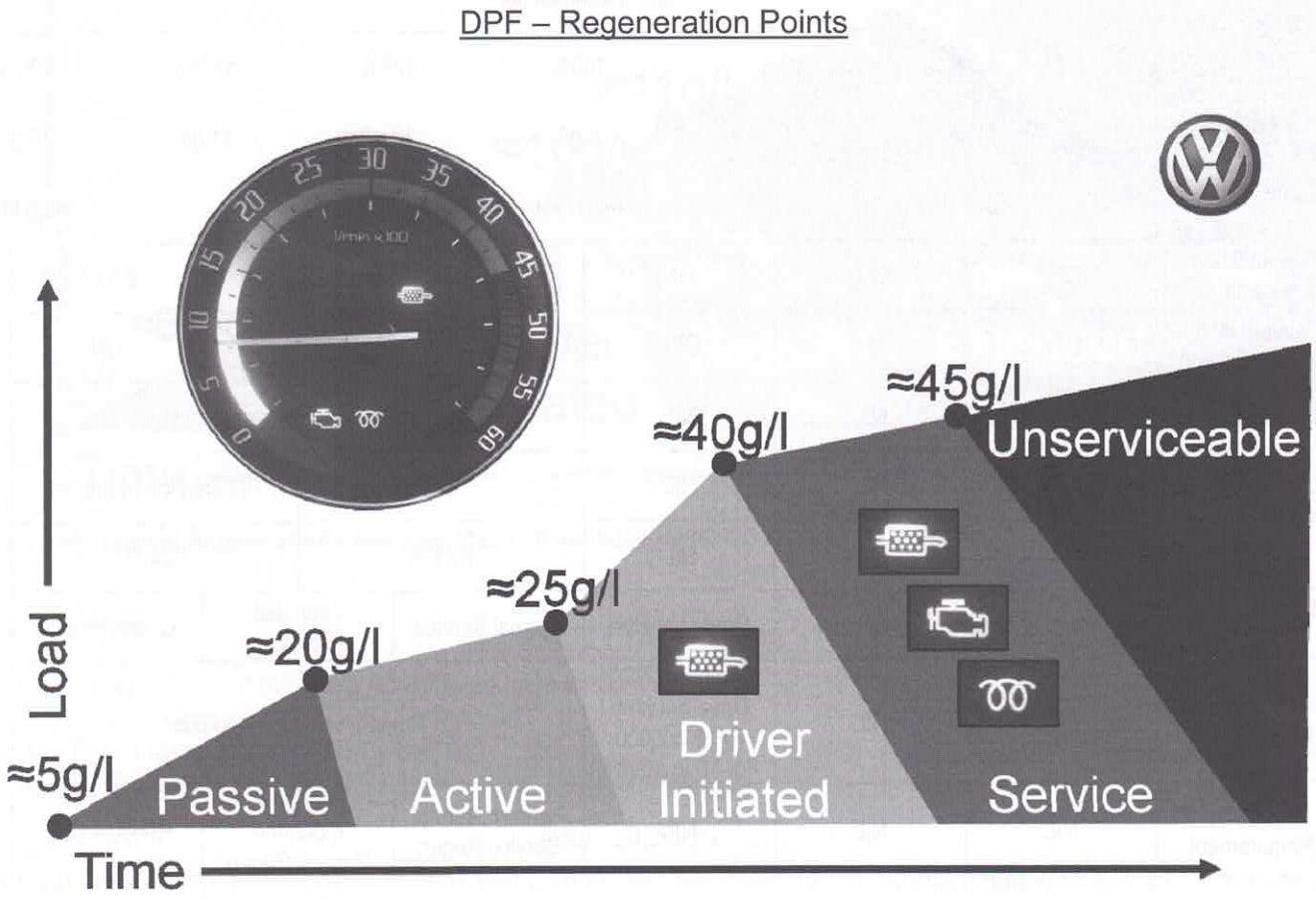


Figure 48: Typical regeneration points for 2010-12MY VAG vehicles (TDI eng.)

DPF – DIAGNOSIS & REGENERATION continued...

Mazda MZR-CD

The following Mazda MZR-CD system is based on the 2.2L MZR-CD engine as fitted to a 2009-11 Mazda6. This is Mazda's second generation MZR-CD system, it was preceded by the 2.0L MZR-CD from 2006-2009 and succession began in 2012 to the 2.2L SkyActive-D system. While the information is directly related to the 2009-11 Mazda6 2.2L MZR-CD the preceding and succeeding variations work in a very similar manner.

DPF – Regeneration Point table

Table 5: Typical regeneration points for Mazda 6 vehicles (MZR-CD eng.)

	DPF Accumulation					
PM (%)	60%	80%	100%	125%	140%	200%
PM (g/l)	5 g/l	6.5 g/l	8 g/l	10 g/l	11 g/l	15 g/l
Differential Pressure (kPa)	0 kPa		≈4.0 kPa	≈5.0 kPa		≈8.0 kPa
DPF Indicator Lamp	OFF	OFF	ON	2.5 Hz	2.5 Hz	2.5 Hz
Malfunction Indicator Lamp	OFF	OFF	OFF	OFF	OFF	ON
Limp Mode #1	NIL	NIL	NIL	Exhaust temperature restricted		
Limp Mode #2	NIL	NIL	NIL	NIL		PM creation restricted
DTC logged	NIL	NIL	NIL	P2458		P242F
Regeneration Mode	Passive	Active	Driver Initiated	Normal Service	Extended Service	Unserviceable
Driver Requirement	NIL	NIL	Engine @ NOT Drive ≥40kmh RPM ≥ 2,000 For 10 to 15 min	Present vehicle to repairer		
Repairer Requirement	NIL	NIL	NIL	Perform Normal Service Regen	Perform Extended Service Regen	Replace DPF

DPF – DIAGNOSIS & REGENERATION continued...

DPF – Regeneration Point graph

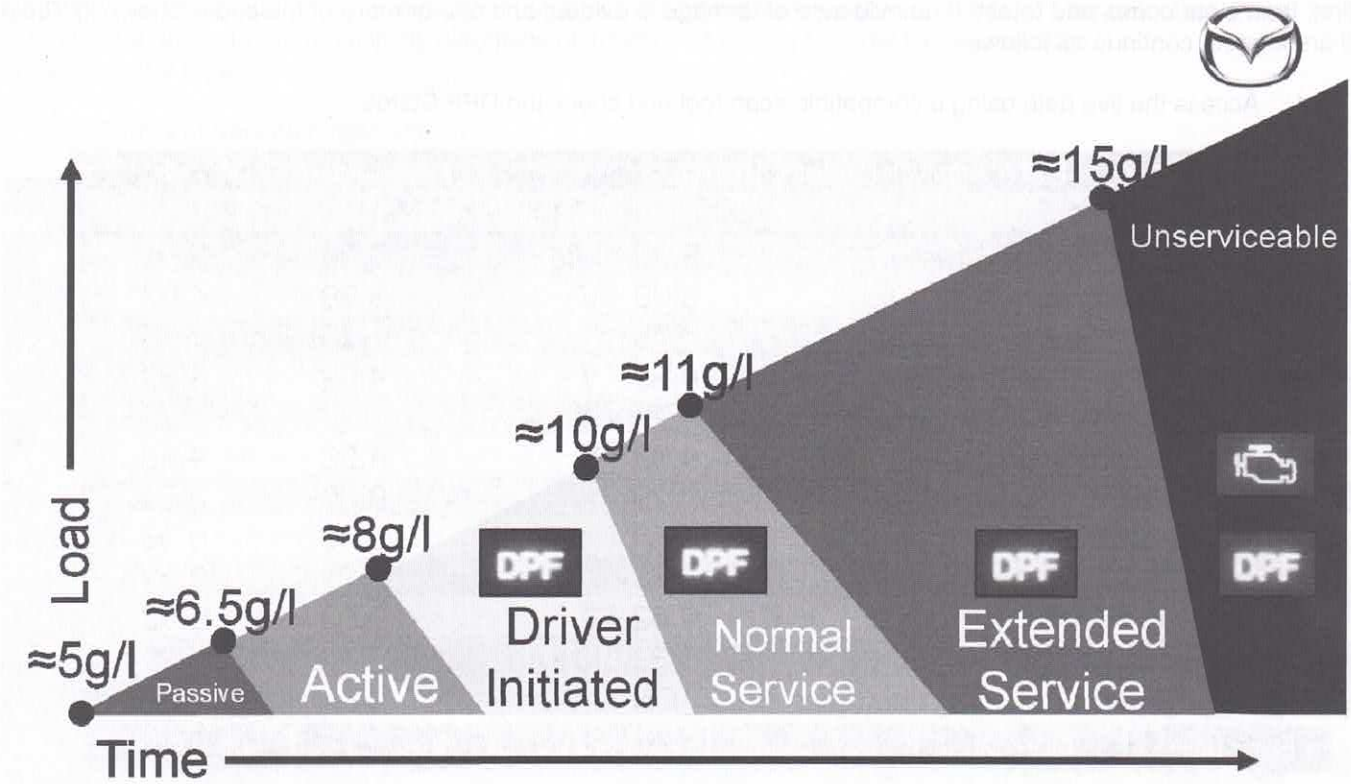


Figure 49: Typical regeneration points for Mazda 6 vehicles (MZR-CD eng.)

Fault Presentation

The following is a list of the likely complaints from the driver:

- DPF Indicator Lamp (DPF) illuminated
- DPF Indicator Lamp (DPF) flashing
- DPF Indicator Lamp (DPF) flashing and MIL illuminated

Basic Inspection

The first step in diagnosing a DPF malfunction is to assess the extent of DPF contamination (*Table 5 on Page 48* sets out accumulation levels for the MZR-CD system):

1. Document customers average driving habits
2. Visually inspect DPF, DPF sensors and wiring for physical damage
3. Check for Fault Codes

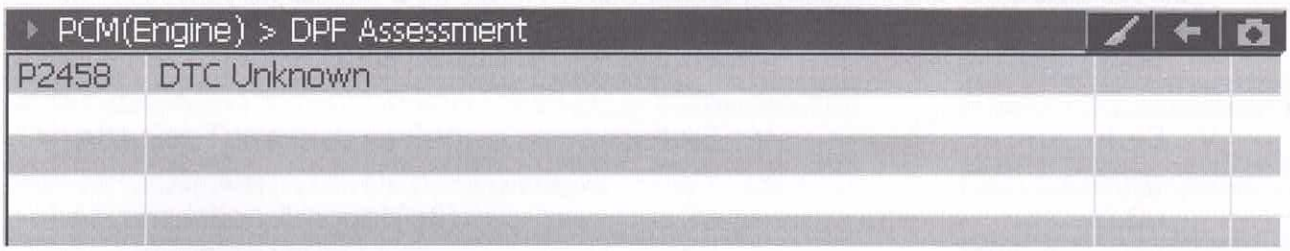


Figure 50: DTC output from 2009 Mazda 6 (MZR-CD eng.) with excessive Particulate Matter (PM) accumulation.

Note: DTC P2458 = Diesel Particulate Filter – Regeneration.

DPF – DIAGNOSIS & REGENERATION continued...

Detailed Inspection

If the basic inspection found physical damage to the DPF or its associated components, these must be addressed first, then clear codes and retest. If no evidence of damage is evident and one or more of the codes shown in *Table 5* are logged, continue as follows:

1. Access the live data using a compatible scan tool and check the DPF Status

PCM(Engine) > Data Analysis(Select Item)

Item	Value	Unit	Min	Max
Exhaust Gas Differential Pressu...	5.20	kPa	5.20	5.26
Exhaust Gas Differential Pressu...	3.98	V	3.98	4.02
Exhaust Gas Temperature Sen...	75	'C	75	75
Exhaust Gas Temperature Sen...	4.89	V	4.89	4.89
Exhaust Gas Temperature Sen...	77	'C	77	77
Exhaust Gas Temperature Sen...	4.88	V	4.88	4.88
Exhaust Gas Flow Amount(mm...	0.29		0.29	0.29
PM Accumulation Amount(g/l)	0.33		0.33	0.33
PM Accumulation Amount Desi...	0.33		0.33	0.33
PM Generation Amount(g/l)	9.62		9.62	9.62
Distance Since Last DPF Rege...	1275.21	Km	1275.21	1275.21
DPF Regeneration Failure Cond...	ON		-	-

Function | Normal | Graph | Record | All Items

Figure 51: DTC output from 2009 Mazda 6 (MZR-CD eng.) with excessive Particulate Matter (PM) accumulation.

2. Values that show reason for fault code detection:

- **Exhaust Gas Differential Pressure = 5.20 kPa**
  This is caused by resistance across the DPF substrate, this should be 0.00 kPa after regeneration because the base value is set to zero with a scan tool when installed. 0.00 to 4.00 kPa is the normal operating range.
- **Exhaust Gas Differential Pressure = 3.98 V**
  This is the actual voltage value measured by the ECM for the pressure equivalent
- **PM Generation Amount (g/l) = 9.62**
  This is the inferred quantity of PM (soot) build up in the DPF, it is based on the Exhaust Gas Differential Pressure. It should be 0.00 g/l after regeneration because the base value is set to zero with a scan tool when installed. 0.00 to 8.00 g/l is the normal operating range.
- **Distance Since Last DPF Regeneration = 1275.21 km**
  This is not a clear cut diagnostic point because the amount of soot trapped will depend on the way the vehicle is driven and the quality of the fuel used. However, most vehicles will perform at least once every 1,000km's.

DPF – DIAGNOSIS & REGENERATION continued...

Perform Repair

The analysis of the data in *Figure 51* indicates that there is excessive accumulation of PM in the DPF, coupled with the Distance Since Last DPF Regeneration value of 1275.21km and the absence of DTC's for any other components, leads to the most likely diagnosis of insufficient driving to allow for regeneration.
To perform the repair:

1. Carry out Service Regeneration

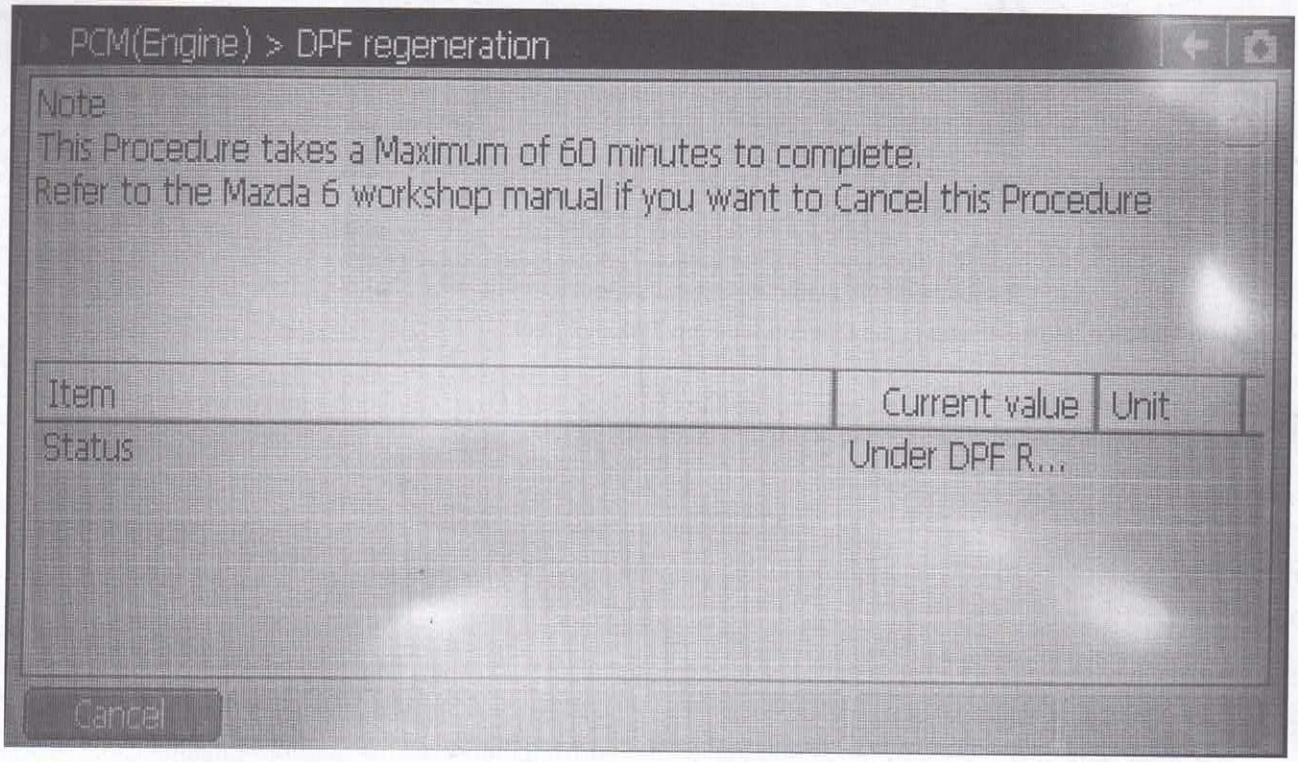


Figure 52: DPF regeneration in progress - 2009 Mazda 6 (MZR-CD eng.)

Note: *Normal DPF Regeneration = 37 minutes*
Extended DPF Regeneration = 60 minutes.

2. Compare live data from before and after Regeneration

Item	Value	Unit	Value	Unit
Exhaust Gas Differential Pressu...	5.20	kPa	0.00	kPa
Exhaust Gas Differential Pressu...	3.98	V	0.99	V
Exhaust Gas Temperature Sen...	75	'C	148	'C
Exhaust Gas Temperature Sen...	4.89	V	4.66	V
Exhaust Gas Temperature Sen...	77	'C	191	'C
Exhaust Gas Temperature Sen...	4.88	V	4.43	V
Exhaust Gas Flow Amount(mm...	0.29		0.38	
PM Accumulation Amount(g/l)	0.33		0.00	
PM Accumulation Amount Desi...	0.33		0.00	
PM Generation Amount(g/l)	9.62		0.01	
Distance Since Last DPF Rege...	1275.21	Km	0.00	Km

Figure 53: DTC output from 2009 Mazda 6 (MZR-CD eng.) before regeneration (left) and after regeneration (right)

DPF – DIAGNOSIS & REGENERATION continued...

3. Check oil level.

   Mazda states that after DPF Regeneration the engine oil level should be assessed for excessive oil dilution (see *Figure 54*).

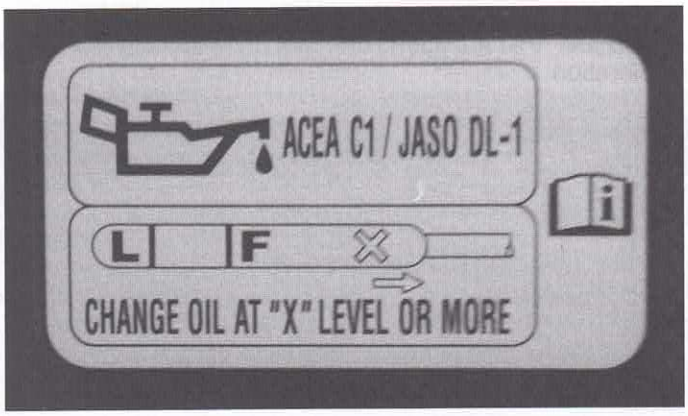


Figure 54: 2009 Mazda 6 (MZR-CD eng.) - Oil dilution label on Tappet Cover.

Note: *While Mazda recommends monitoring the oil dilution level, many manufacturers state that an engine oil and filter change MUST be completed after a Service Regeneration.*

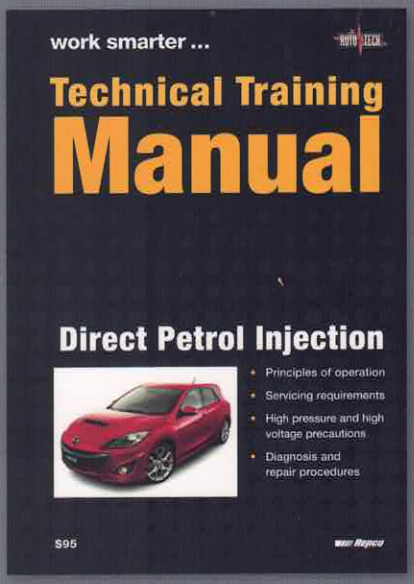
Verifying the repair

To verify that the repair carried out has addressed the customer's complaint, ensure the following steps are carried out:

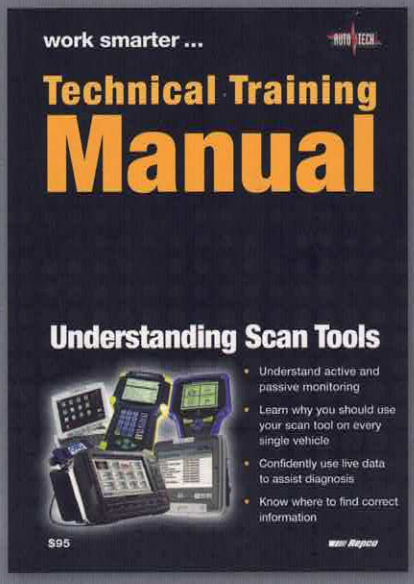
1. Erase DTCs
2. Reproduce Fault Conditions
3. Re-check DTCs
4. Confirm Vehicle Operation
5. Discuss with customer how they may need to alter their driving habits to prevent further malfunctions and reduced DPF service life.

AUTO TECH

Technical Training Manuals available:



Direct Petrol Injection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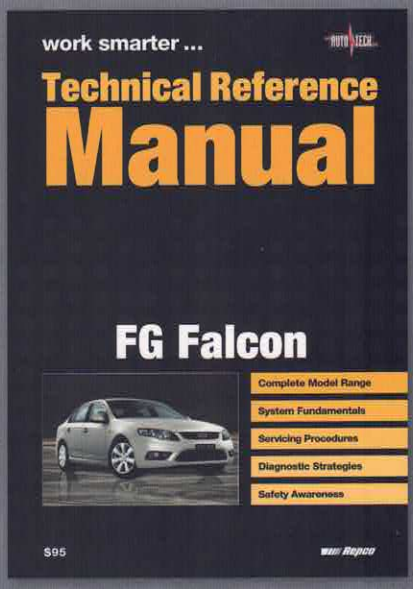
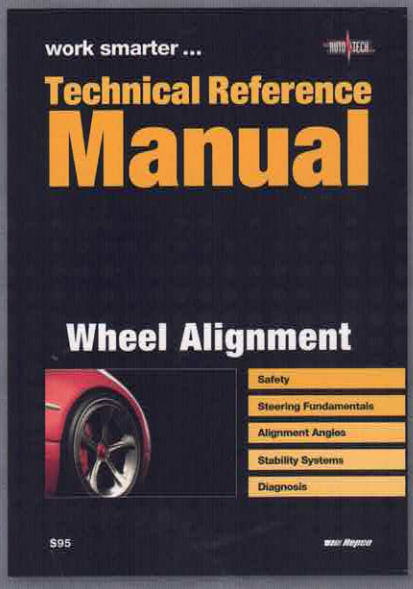
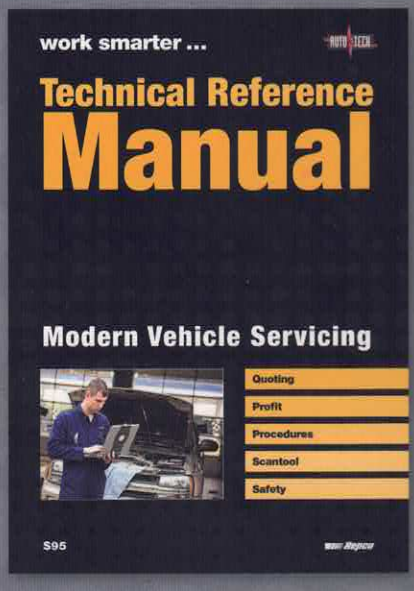
Understanding Scan Tools



FG Falcon



Wheel Alignment



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